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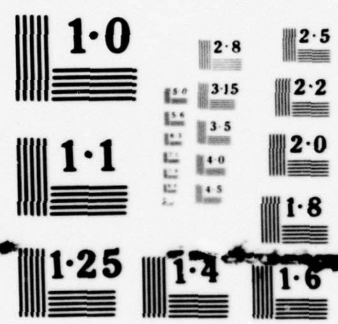

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NSWC/WOL TR 76-69

FINAL REPORT ON IN-HOUSE EXPLORATORY DEVELOPMENT PROGRAM ON MICROSTRIP ANTENNAS

BY J. W. McCORKLE
L. M. BLACK

ADVANCED WEAPONS DEPARTMENT

28 FEBRUARY 1978

NAVAL SURFACE WEAPONS CENTER

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This report describes some of the basic forms of the microstrip patch antenna and gives a general theory of operation. It then goes into the derivation of a previously unpublished design procedure for the rectangular patch radiator. The computer aided design procedure is explained in detail.

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SUMMARY

This report describes some of the basic forms of the microstrip patch antenna and gives a general theory of operation. It then goes into the derivation of a previously unpublished design procedure for the rectangular patch radiator. The computer aided design procedure is explained in detail.

R. T. RYLAND, JR.
By direction

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INTRODUCTION

Due to its adaptability to a wide variety of aircraft, missile, projectile and phased array applications, the microstrip patch antenna has become a subject of great interest to antenna and systems designers through the scientific community.[1] It is of particular interest in areas where the thickness, cost, and reliability of the antenna are of prime importance such as in projectile fuzing applications. Stripline slot antennas, although equally adaptable to many systems, have proven to be too costly and unreliable in many instances. Much has been said and written regarding the various forms of the microstrip patch antenna and their potential uses. Reference 2 in particular gives a good overall view, and Reference 3 provides additional data; however, there is very little information in the literature which could be classified as basic design data. The Naval Surface Weapons Center has undertaken an in-house exploratory effort directed towards producing and disseminating a practical design procedure.

BASIC MICROSTRIP PATCH RADIATOR

Figures 1 and 2 show a microstrip patch radiator etched on a teflon fiberglass substrate. In this particular configuration, as shown in Figure 3, energy is fed to the patch through the substrate. The patch can also be fed on its edge as shown in Figure 4, or notch fed as in Figure 5. The latter two feed methods are in fact the most commonly used. They allow the entire feed network to be etched on the same substrate as the patch, a definite advantage in multi-patch applications, an example of which is shown in Figure 6.

---

1. Black, L. M., and McCorkle, J. W., "Preliminary Report on the In-house Exploratory Development Program on Microstrip Antennas," NSWC/WOL TR 75-200, December 1975.

2. Khulman, E. A., Microstrip Antenna Study for Pioneer Saturn/Uranus Atmosphere Entry Probe, NASA Report CF-137513.

3. Munson, R. E., Conformal Microstrip Antennas and Microstrip Phased Array, IEEE Transactions on Antennas and Propagation, January 1974.

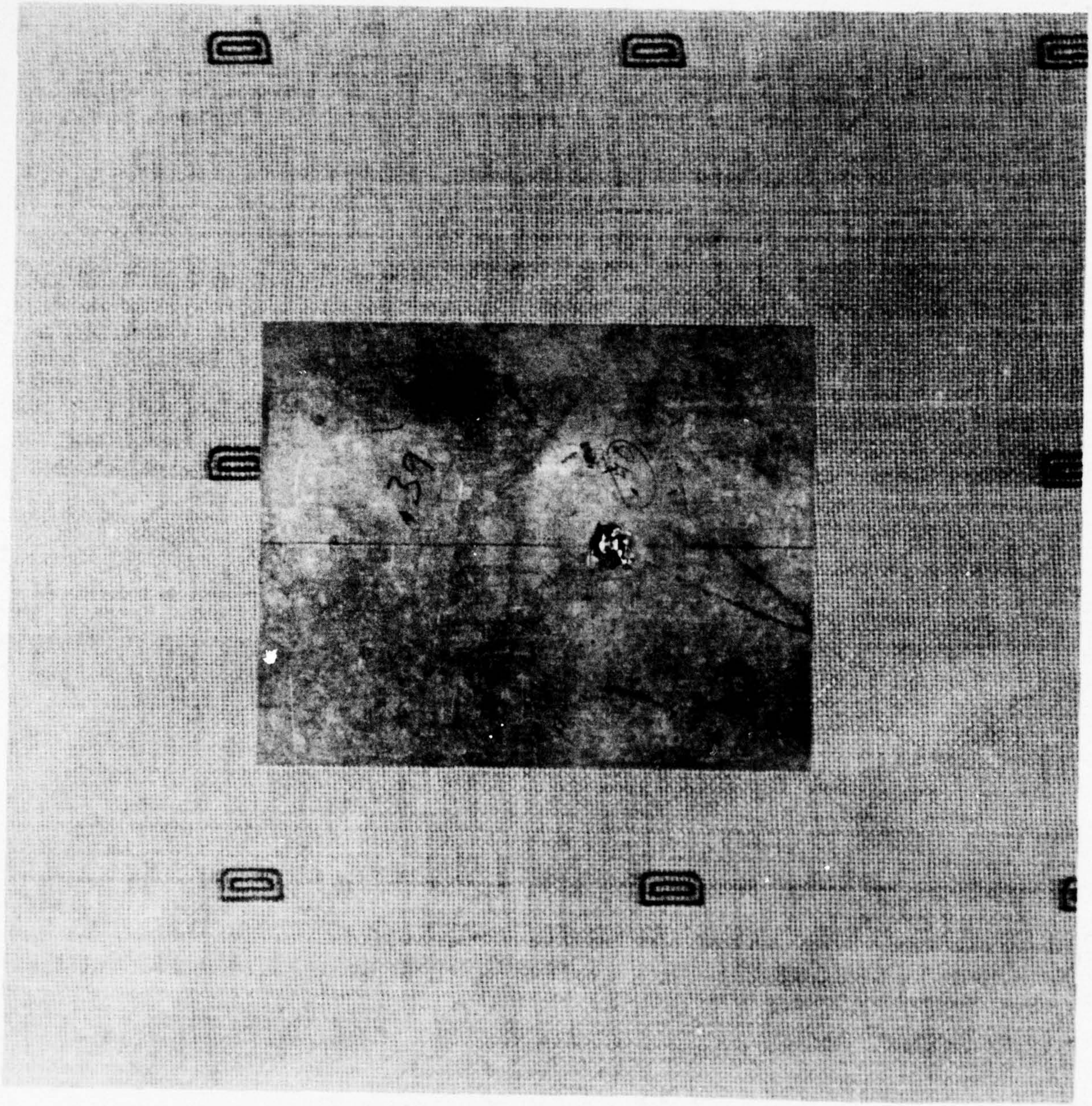


FIG. 1 BACK FED MICROSTRIP PATCH RADIATOR FRONT VIEW

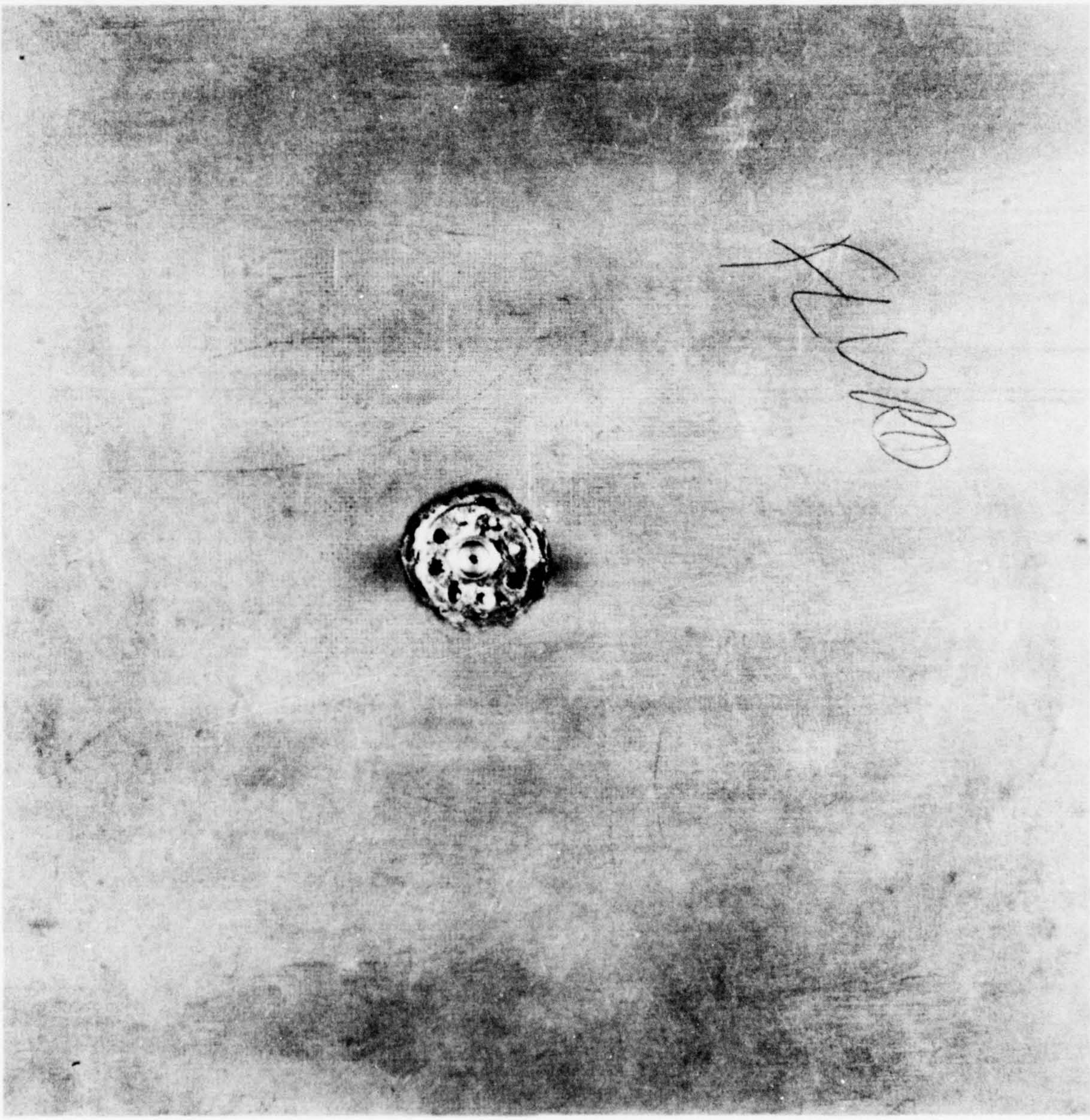


FIG. 2 BACK FED MICROSTRIP PATCH RADIATOR REAR VIEW

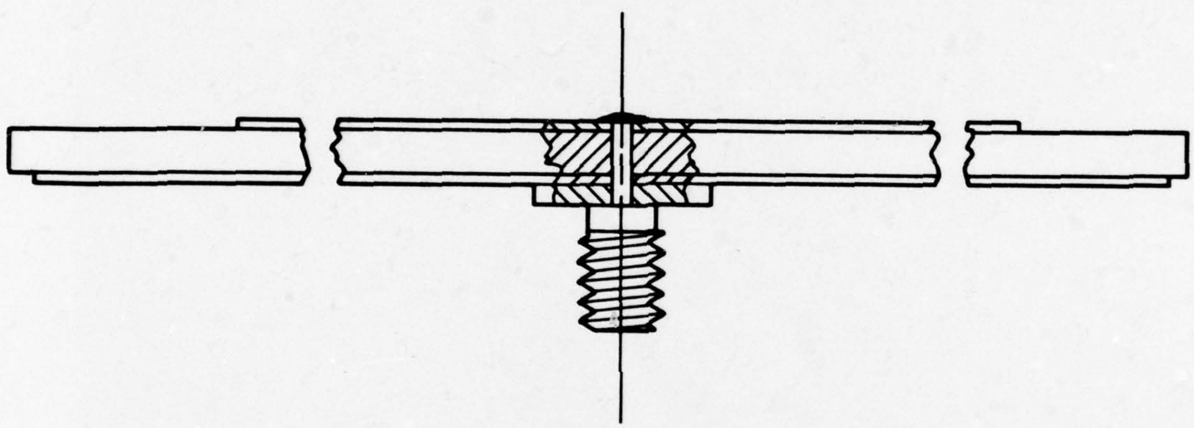


FIG. 3 DETAIL OF PATCH RADIATOR REAR FEED STRUCTURE

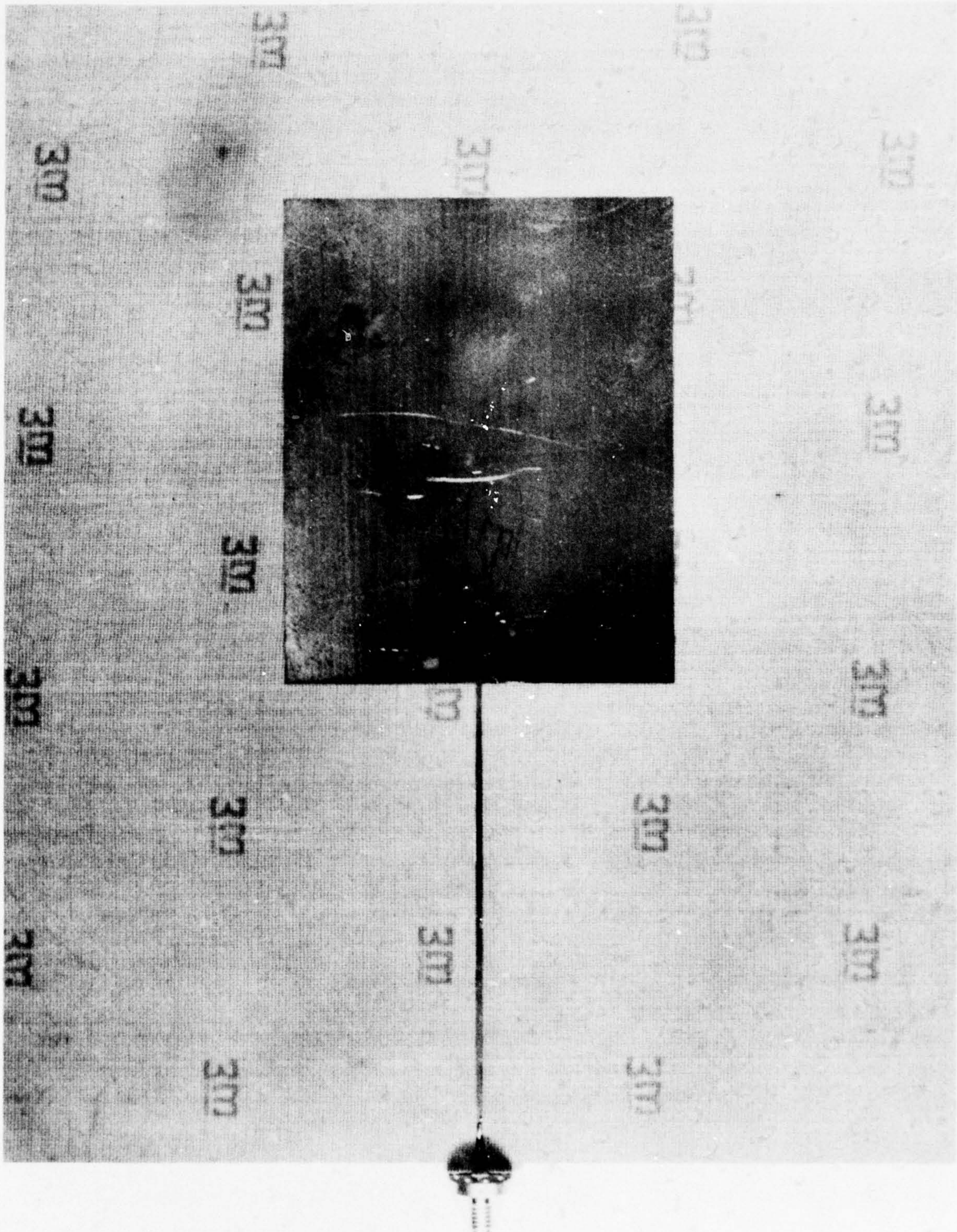


FIG. 4 EDGE FED MICROSTRIP PATCH RADIATOR

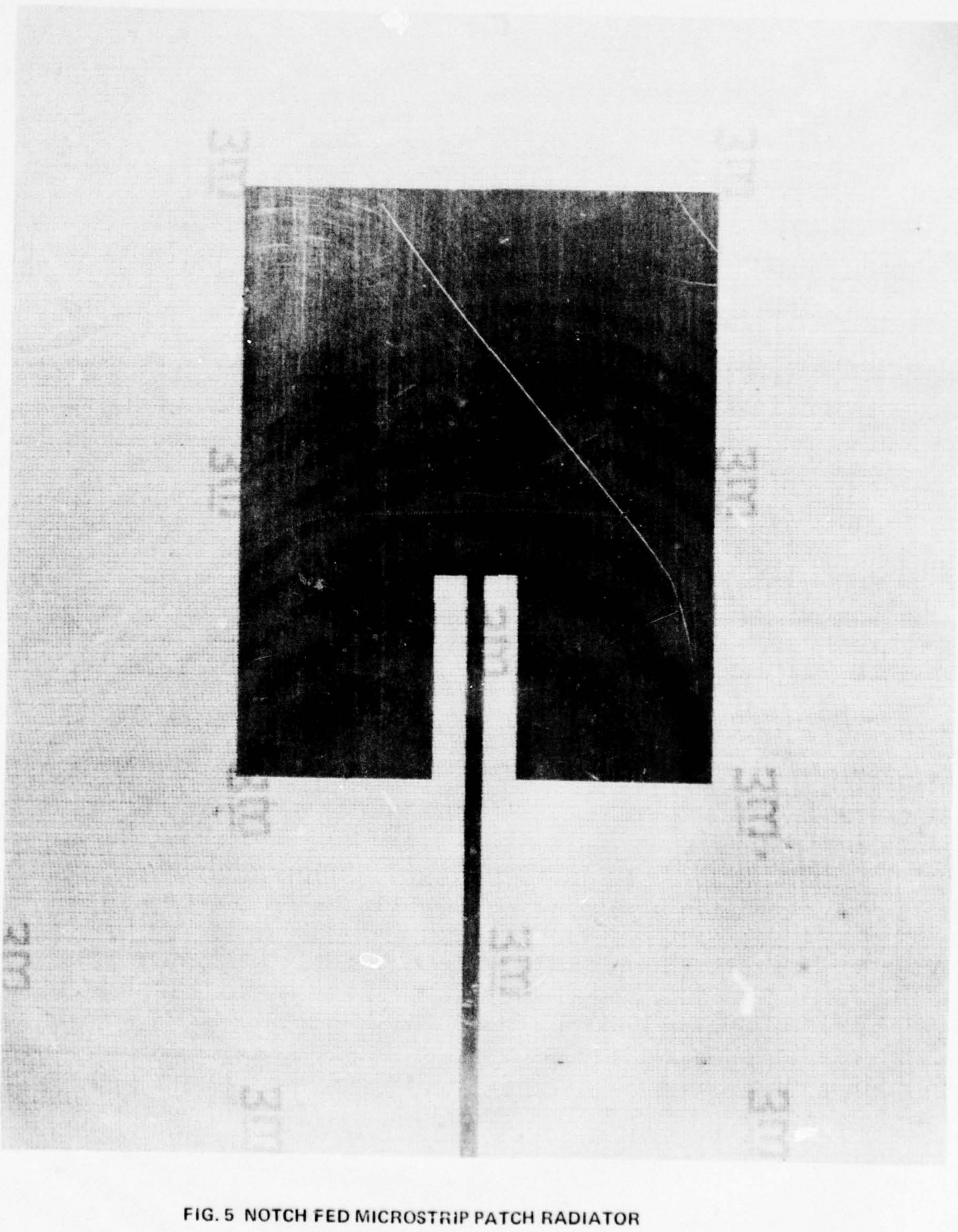


FIG. 5 NOTCH FED MICROSTRIP PATCH RADIATOR

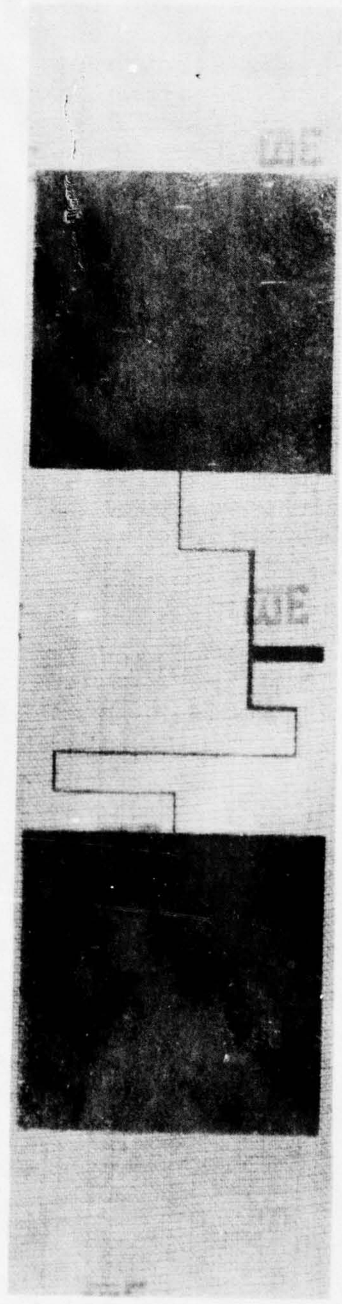


FIG. 6 MULTIPATCH MICROSTRIP TELEMETRY ANTENNA

DESIGN PROBLEM

There are two basic design problems associated with the design and construction of a microstrip patch antenna. These are the determination of the dimensions of the patch itself, and the determination of the input impedance at a given point on the patch. They are a function of the thickness of the substrate, the dielectric constant of the substrate material, the operating frequency, the patch feed itself, and ground plane size. Figure 7 is a diagram of the microstrip patch and all of its parameters.

GENERAL THEORY OF OPERATION

There are three (3) independent modes of oscillation which can occur on the back fed microstrip patch antenna. A wave can oscillate between the ends of the patch along the 'A' dimension. When 'A' is close to a half wave length, this is analogous to a simple half wave dipole antenna.

A second mode of oscillation can be set up along the 'B' dimension. Also, a third mode can be set up along the pin used to feed the patch. This mode is referred to as the monopole mode since the pin can be thought of as a top loaded monopole over a ground plane where the patch is the capacitive top hat.

The input impedance of the microstrip patch is a function of Y_o and all three modes. Just like a half wave dipole, the impedance at the center ($Y_o = 0$) is low, and the impedance at the end ($Y_o = A/2$) is very high. Either or both modes A and B can be utilized by properly choosing Y_a and Y_b.

INITIAL STUDY

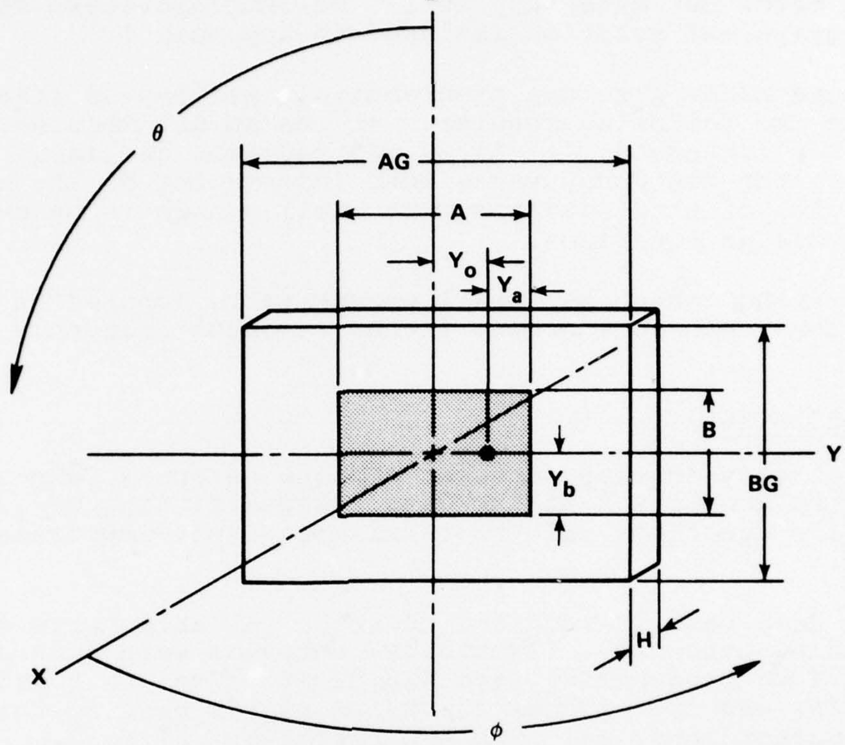
Initially, the computer was programmed with Kaloi's equations to determine the input impedance, the antenna gain pattern, the resonant frequency, and the bandwidth. It was in this period that several corrections were made to Kaloi's paper (Reference 4).

Kaloi's equations were based on there being only one mode excited to simplify the calculations. His equation for determining the length of the antenna (1) has been found to be very accurate.

From Reference 3:

$$A = \left(\frac{5.9}{(F(GHz)} - 2H\sqrt{E_r}\right)\left(1 + .61\,(E_r-1)(B/H)^{.1155}\right)^{-1/2} \qquad (1)$$

4. Kaloi, C. M., Asymmetrically Fed Electric Microstrip Dipole, Naval Missile Center, Point Mugu Technical Publication, TP-75-03.



A = PATCH LENGTH INCHES
B = PATCH WIDTH INCHES
H = SUBSTRATE THICKNESS INCHES
Y_o = FEED POINT INCHES
E_r = SUBSTRATE DIELECTRIC CONSTANT
γ = SUBSTRATE LOSS TANGENT
AG = GROUND PLANE LENGTH
BG = GROUND PLANE WIDTH

FIG. 7 ANTENNA COORDINATE SYSTEM WITH PARAMETERS DEFINED AS FOLLOWS:

Unfortunately, his equations for determining the input impedance yielded VSWR's as high as 3.5:1.0. However, the $\sin^2$ distribution was found to match our data very well. We combined these results into a semi-graphical solution included in Appendix 1.

The ground plane size was progressively reduced on several antennas with the following results: (1) As AG was reduced, the input impedance increased; (2) As BG was reduced, the input impedance decreased; (3) The frequency was almost independent of the ground plane size. All of these changes were small enough to be neglected in the final design equations.

Another trend, which was small enough to be ignored in the final design equations, was an increase in the resonant frequency as Y_o increased.

COMPUTER-AIDED STUDY

Having already acquired data on a dozen antennas, the computer was enlisted to keep track of the data. Curve fitting was used to augment Kaloi's equations such that reliable input impedances could be predicted.

A large data base is required to get a reliable curve fit, so we started building antennas. Eventually, antennas were made and data was taken on four frequencies from 400 MHz to 2GHz, on boards that were 1/8, 1/16, and 1/32 inches thick, on boards made by three different manufacturers, and with A/B ratios of .67 to 2.0. In all, over 60 antennas were built and tested with each succeeding set of antennas based on results obtained with all of the preceding antennas.

Ten (10) programs and eleven (11) subroutines were eventually written and used in the process of the study. As a result of the subroutine oriented organization of the programs, other users can easily calculate any antenna parameter required. A complete listing of all of the programs is included in Appendix 2.

FINAL RESULTS

Based on approximately 60 antennas, the maximum VSWR was 1.3:1.0 and the average VSWR was 1.1:1.0. Program MICROAN allows anyone to design a complete back fed microstrip antenna via a teletype terminal. An example run is shown in Figure 8 and a flow diagram for MICROAN is shown in Figure 9. The only limitations to this program are that the conditions $H < 1/8$ and $A/B > 1$ be met.

ADDITIONAL WORK

Antenna patterns were measured on several antennas. Very good agreement between the calculated patterns and measured patterns was obtained.

```
RFL,40000
RFL,40000.
/GET,MICROAN/UN=685.
/GET,SUBS/UN=685.
/LINK,F=MICRØAN,F=SUBS,X.
 TYPE IN THE FOLLØWING PARAMETERS.
 FREQ IN GHZ
 A/B RATIØ
 HEIGHT IN INCHES
 DIELECTRIC CØNSTANT
 DESIRED INPUT RESISTANCE
 CØRRECTION FACTØR = MEASURED/CALCULATED INPUT RESISTANCE ØF A TEST ANTR
 LØSS TANGENT
? 1.5 1.2 .062 2.5 50. 1. .001
 LENGTH A                    =     2.428964
 WIDTH B                     =     2.024137
 YO                          =      .315815
 Y1=A/2 - YO                 =      .898667
 ØHMS PER .01"  CHANGE IN YO =     2.961955
 ØHMS PER .001'' CHANGE IN H =      .300867
 -3DB BANDWIDTH (GHZ)        =      .037377
 GAIN (DB ØVER ISØTRØPIC)    =     5.122167
 INPUT RESISTANCE            =    50.000000
 FREQUENCY IN GHZ            =     1.500000
 A/B RATIØ                   =     1.200000
 SUBSTRATE HEIGHT            =      .062000
 DIELECTRIC CONSTANT         =     2.500000
 LØSS TANGENT                =      .001000
 CØRRECTIØN FACTØR           =     1.000000
 RO                          =   336.537973
 P                           =     1.252934
  IF YØU HAVE NØ MØRE DATA TYPE IN 'STØP'
? .172 10. .062 2.35 50. 1. .0005
 LENGTH A                    =    22.754675
 WIDTH B                     =     2.275468
 YO                          =     1.350314
 Y1=A/2 - YO                 =    10.027023
 ØHMS PER .01"  CHANGE IN YO =      .729444
 ØHMS PER .001'' CHANGE IN H =     1.036038
 -3DB BANDWIDTH (GHZ)        =      .002253
 GAIN (DB ØVER ISØTRØPIC)    =     3.602143
 INPUT RESISTANCE            =    50.000000
 FREQUENCY IN GHZ            =      .172000
 A/B RATIØ                   =    10.000000
 SUBSTRATE HEIGHT            =      .062000
 DIELECTRIC CØNSTANT         =     2.350000
 LØSS TANGENT                =      .000500
 CØRRECTIØN FACTØR           =     1.000000
 RO                          =  1465.634837
 P                           =      .137575
  IF YØU HAVE NØ MØRE DATA TYPE IN 'STØP'
? STØP

 *TERMINATED*

/COST.
APPROX CØST ØF RUN IS $     .56
RETURN(ZZZZCØ)
/
```

FIG. 8 SAMPLE OF COMPUTER AIDED DESIGN PRINTOUT

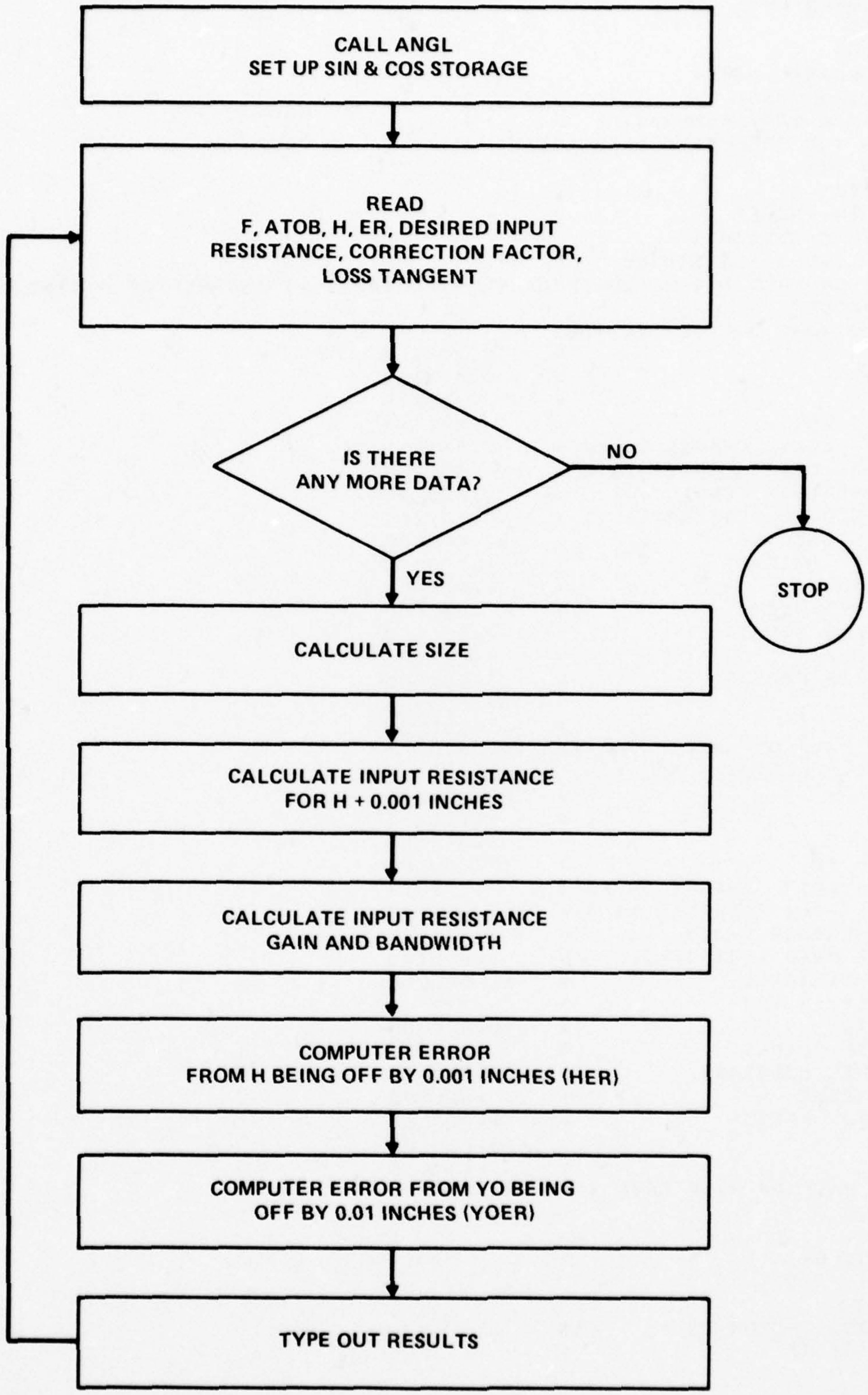


FIG. 9 FLOW DIAGRAM FOR PROGRAM MICROAN

Based on nine notch-fed antennas, a graph has been made which can be used to augment the $\sin^2$ distribution of the antenna input impedance. Upon further development, this could be incorporated into program MICROAN so that notch-fed antennas could be designed via the teletype terminal.

APPENDIX A

Size Calculation

C. M. Kaloi's equation for determining the length of the antenna has been found to be very accurate. The basic problem in finding a concise deisgn procedure for determining the patch dimensions is the fact that 'A' is a function of 'B' as seen in Equation (1) below.

From Reference 3:

$$A = \left(\frac{5.9}{F\,(GHz)} - 2H\sqrt{E_r}\right)\left(1 + .61\ (E_r - 1)(B/H)^{.1155}\right)^{-1/2} \qquad (1)$$

As a result, a design procedure has been set up whereby the ratio of 'A' to 'B' is arbitrarily chosen, followed by the calculation of both 'A' and 'B'. The derivation of the procedure is explained on a step-by-step basis below.

The design procedure is based on frequency scaling and on scaling with the square root of the dielectric constant. The frequency scaling procedure results from an approximation in the first term of Equation (1) as shown in Equation (2) below.

$$\frac{5.9}{F\,(GHz)} - 2H\sqrt{E_r} \approx \frac{5.9}{F\,(GHz)} \qquad (2)$$

Figure 8 shows that this is a fairly good approximation. Dielectric constant scaling results from an approximation in the second term of Equation (1) as shown in Equation (3).

$$\left(1 + .61\ (E_r - 1)(B/H)^{.1155}\right)^{1/2} \approx \sqrt{E_r} \quad (B/H \approx 72) \qquad (3)$$

Figure 9 shows that this is also a fairly good approximation. The basic design tool becomes then, a graph of Equation (1) with the resonant frequency plotted against the A/B ratio, with the parameters 'A', 'H', and 'E_r' specified (graphs where A = 3.7, E_r = 2.5, and H = .015, .031, .062, and .125 are shown in Figure 10). Once this graph is used, frequency scaling and dielectric constant scaling are

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employed to arrive at a close solution. The solution for 'B' can then be plugged back into Equation (1) to remove any errors that might have resulted from the approximations and/or from reading the graph.

Design Procedure for Size Calculation

Step 1. Given

a. Substrate thickness ≡ 'H'

b. Desired resonant frequency ≡ 'F_o'

c. Relative dielectric constant of the substrate ≡ 'E_r'

Step 2. Select an A/B ratio

Step 3. Read the frequency 'F' for the appropriate substrate thickness in Figure 10

Step 4. Multiply 'F' by $\sqrt{\frac{2.5}{'E_r'}}$

Step 5. Calculate A = 3.7 (F/F_o)

Step 6. Calculate B = A/(A/B ratio)

Step 7. To remove any errors, substitute 'B' into Equation (1) and calculate 'A'

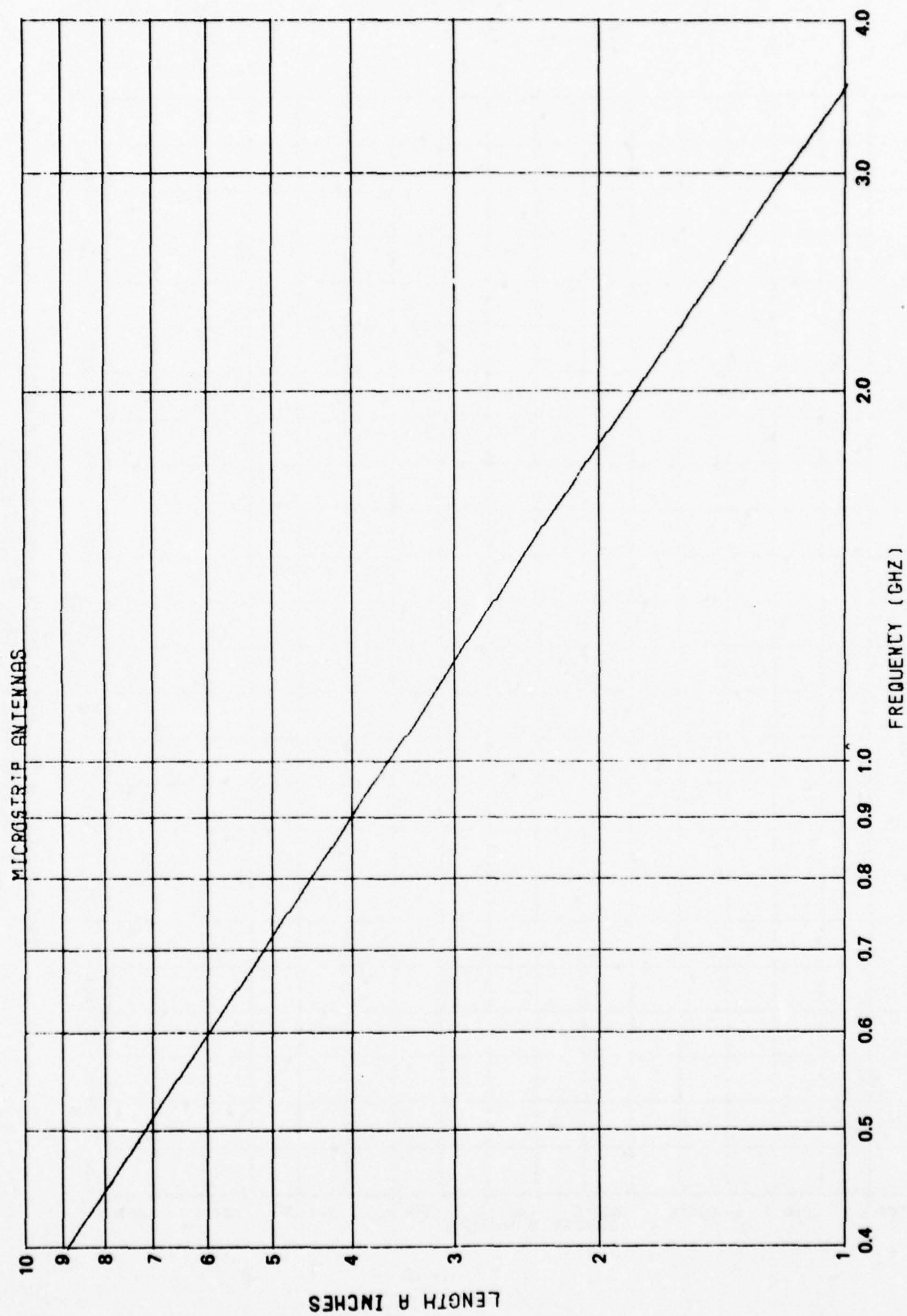


FIG. A-1 LENGTH "A" VERSUS THE RESONANT FREQUENCY WHERE:
B = A, Er = 2.55, H = 0.047 INCHES

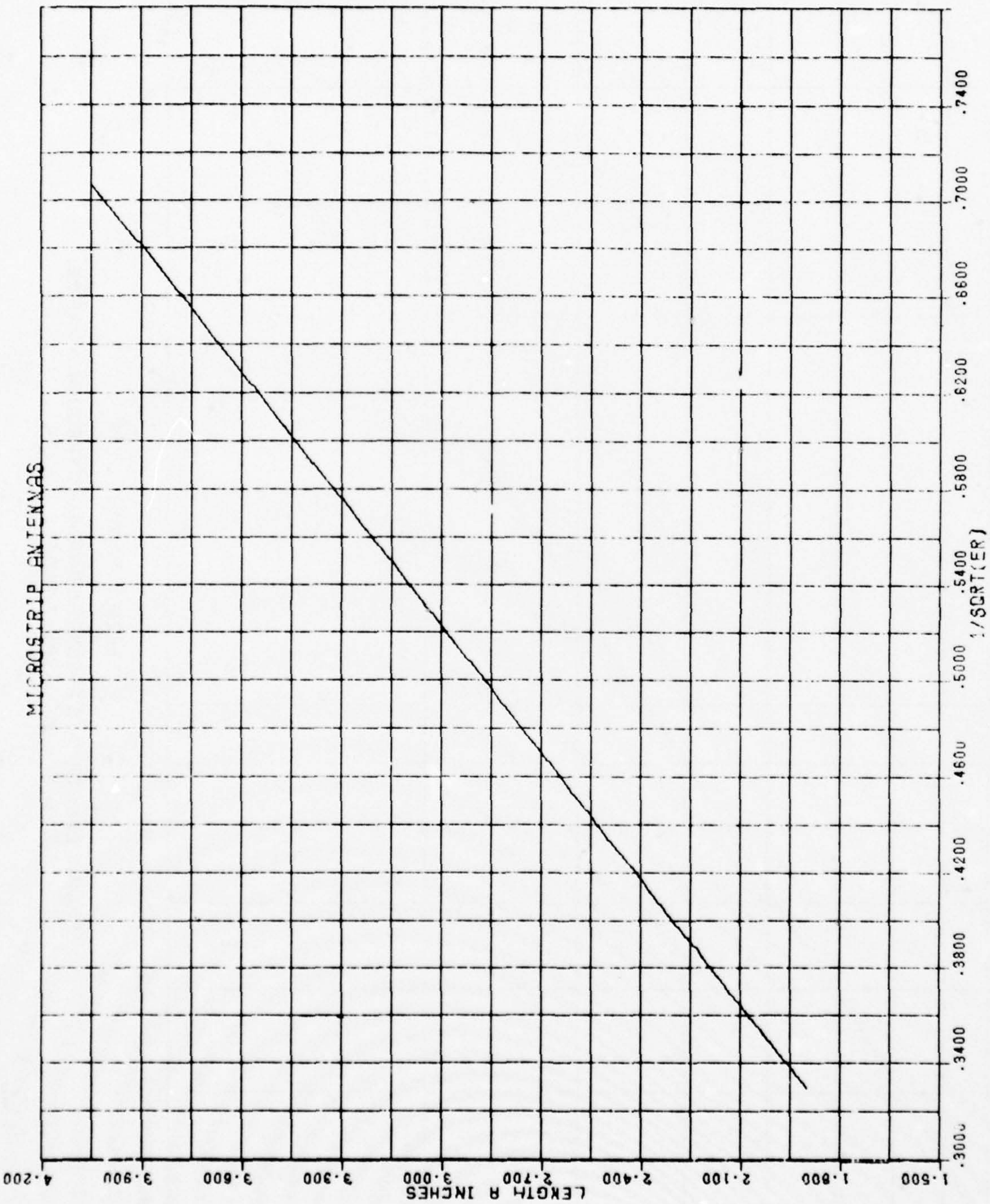


FIG. A-2 LENGTH "A" VERSUS THE SQUARE ROOT OF Er WHERE:
B = A, FREQUENCY = 1 GHZ, H = 0.047 INCHES

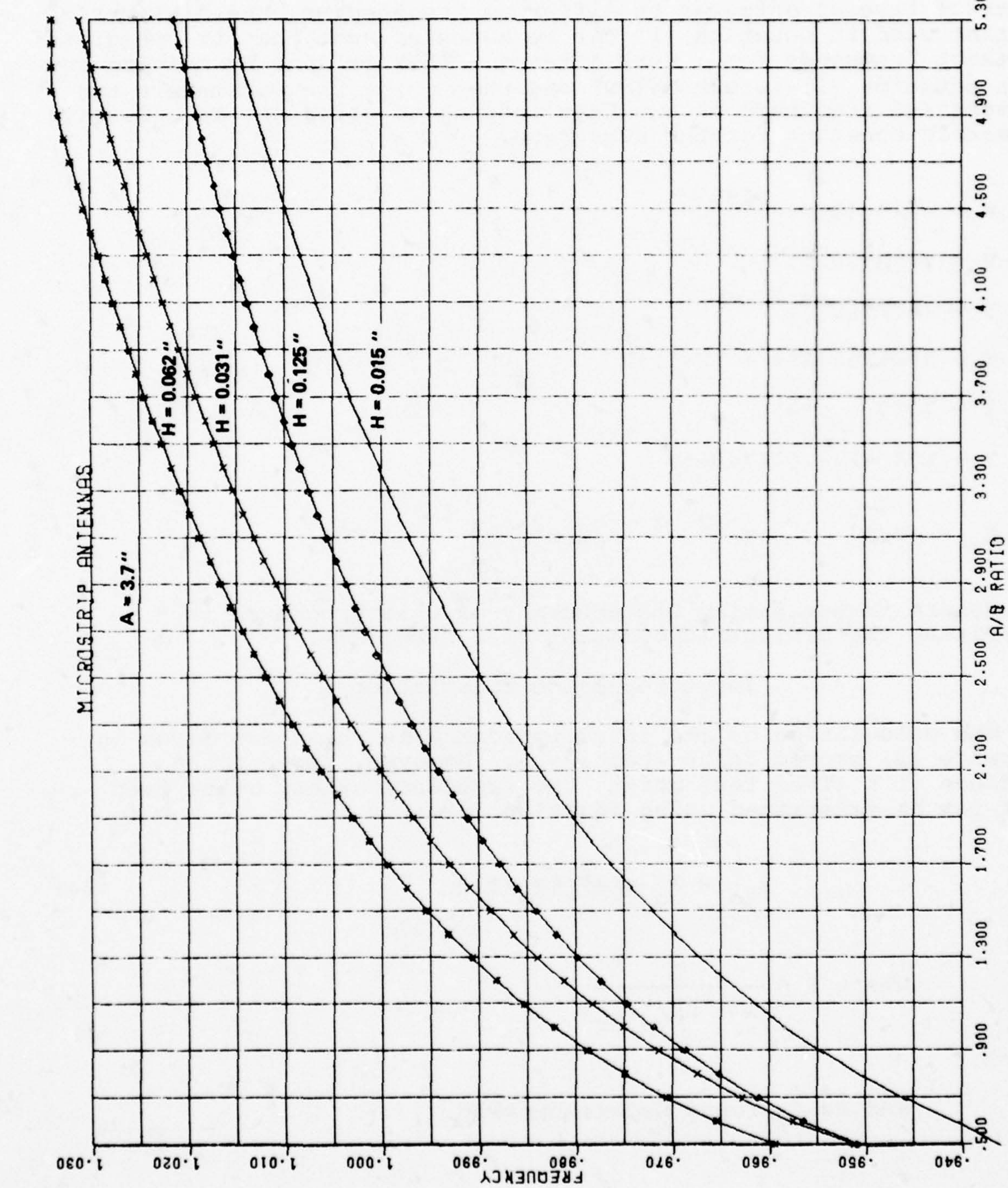


FIG. A-3 BASIC DESIGN CURVES FOR VARIOUS SUBSTRATE HEIGHTS SHOWING THE RESONANT FREQUENCY VERSUS THE A/B RATIO, WITH THE PATCH LENGTH "A" FIXED AT 3.7 INCHES, AND THE DIELECTRIC CONSTANT Er FIXED AT 2.5

Fine Tuning the Calculation

When a particular batch of material is going to be used to construct several antennas of differing frequencies, the dielectric constant used in Equation (1) can be adjusted such that it "predicts" the exact frequency for a test antenna. This is done by solving for E_r in Equation (1) (shown below) and then using the parameters and the measured frequency of the test antenna to calculate an effective dielectric constant for the substrate.

$$W = .61 * (B/H)^{.1155}$$

$$V = (F*H*10^{-9})^2$$

$$U = (A*F*10^{-9})^2$$

$$X = 34.82684258 + (W-1)*V$$

$$Z = (4*V - U*W)$$

$$Y - X*Z - 278.6147406*V$$

$$E_r = -Y/Z^2 - \left[(Y/Z^2)^2 - (X/Z^2)^2\right]^{1/2}$$

We are investigating the accuracy of this procedure in determining the dielectric constant of a substrate.

Input Impedance Calculation

The calculation of the input impedance at resonance given in reference (3) proved to be inaccurate. However, knowing the impedance at a given feed point, the impedance at any other feed point can be determined using Equation (4).

$$R_{in} = R_o \sin^2 (Y_o * P) \tag{4}$$

where $P = \dfrac{\Pi}{A + 2H/\sqrt{E_r}}$

and Ro is found experimentally.

The design procedure would thus be as follows:

Step 1. Determine desired input resistance based on system considerations

Step 2. Build a microstrip antenna at the appropriate frequency and feed it at an arbitrary $Y_o = Y_1$

Step 3. Measure the input resistance 'R_1'

Step 4. From Equation (4) calculate $R_o = R_1/\sin^2 (Y_1 * P)$

Step 5. Calculate 'Y_o' for the desired input resistance using Equation (5).

$$Y_o = \frac{\text{Arcsine}\left(\sqrt{R_{in}/R_o}\right)}{P} \tag{5}$$

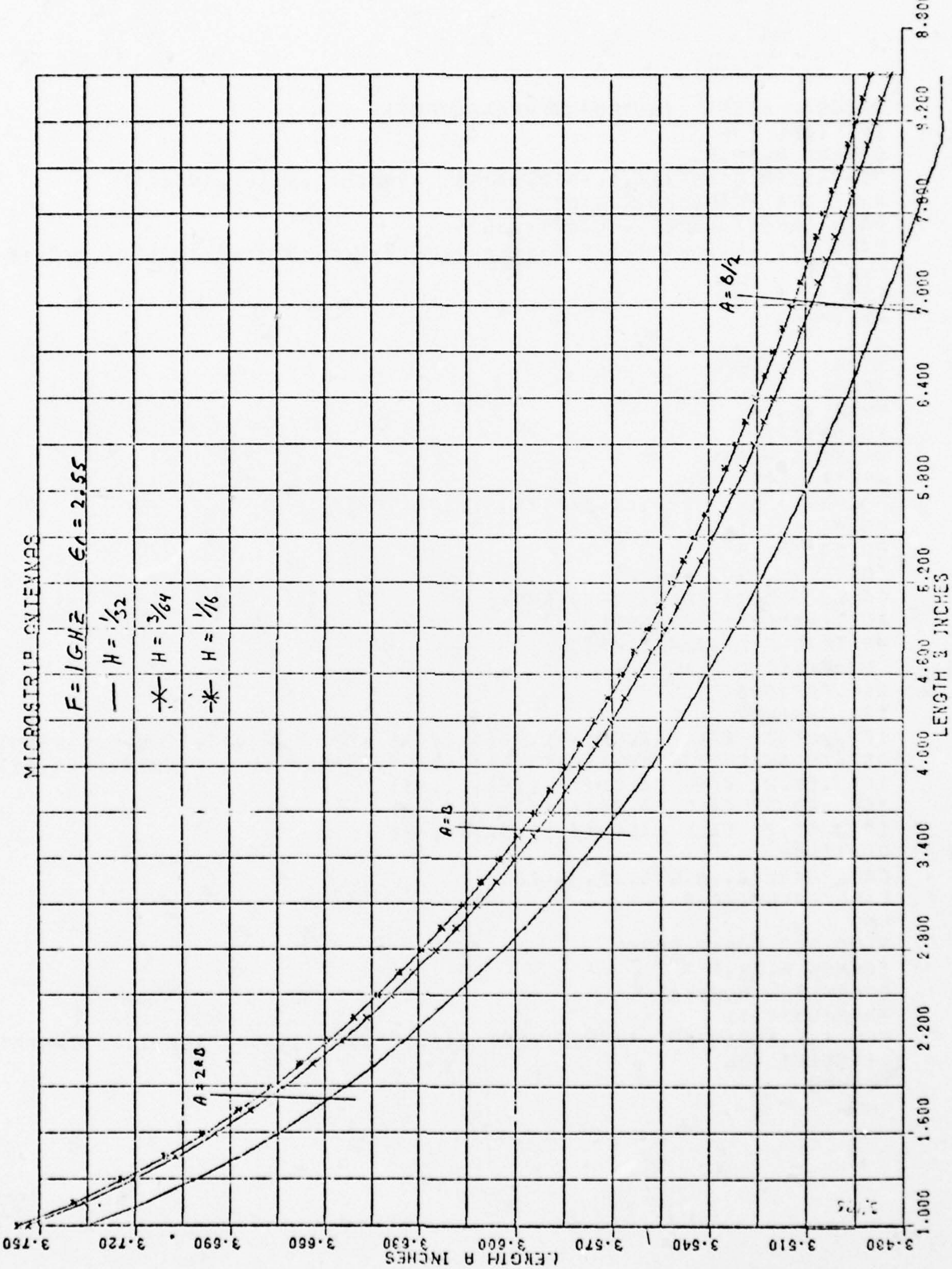
APPENDIX B

Computer Programs and Subroutines

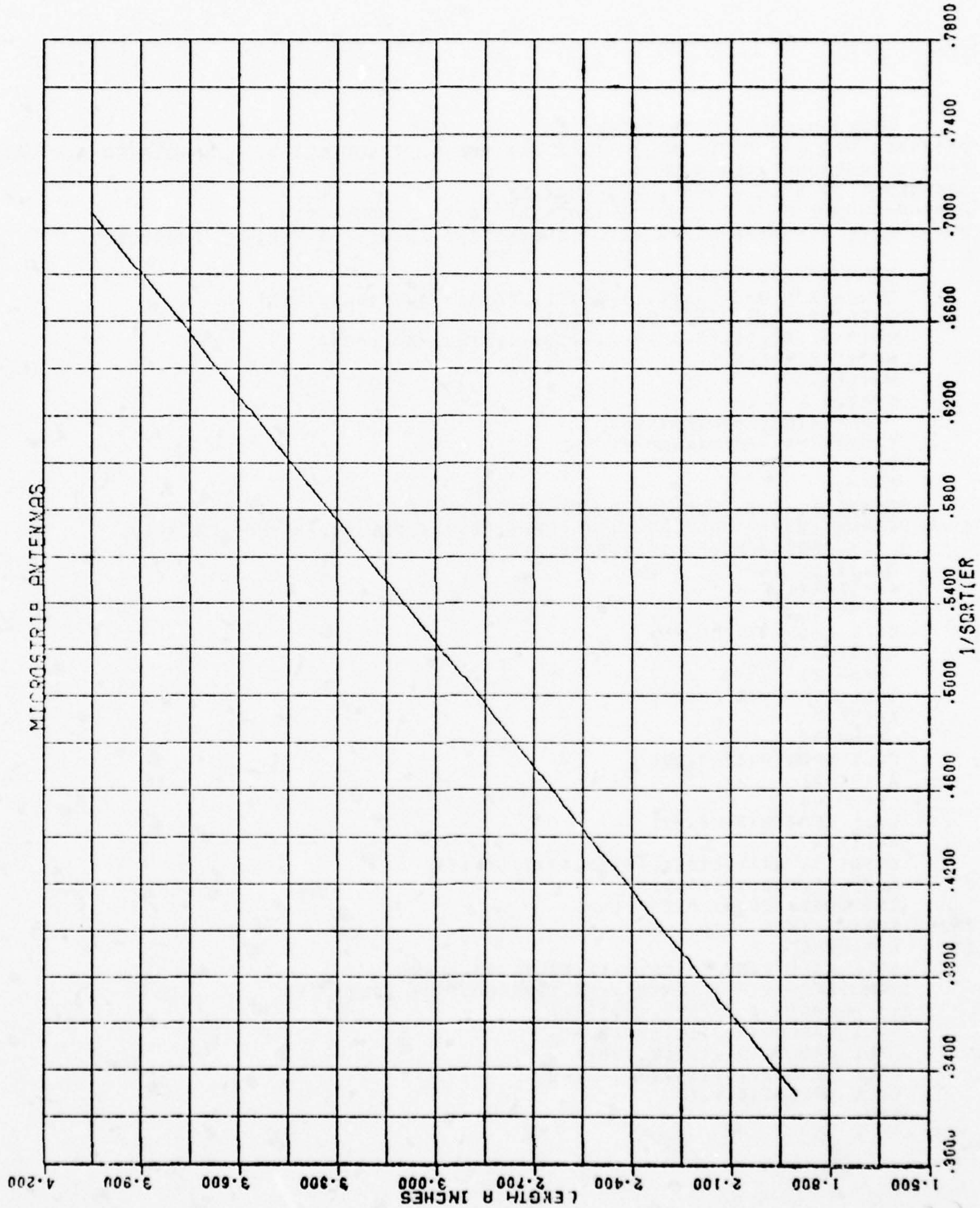
Programs	Subroutines
1. A OF B	1. ANGL
2. A OF ER	2. CONSTAN
3. A VS F	3. DIELECT
4. DRIVE	4. LENGTH
5. E AND H	5. PAT
6. F VS ATOB	6. RIN
7. MICROAN	7. SIMP
8. PATTERN	8. T
9. RESULTS	9. U
10. RIN VS H	10. WATTS
	11. XFIL

Function "XFIL" was taken from the NSWC user library and modified. All other programs were written by John McCorkle.

```
      PROGRAM AOFB(OUTPUT,INPUT)
C     THIS PROGRAM PLOTS LENGTH A VERSUS WIDTH B
      DIMENSION EC(4),HC(3),AL(51),BX(51)
      DATA EC/2.,2.250007629,2.55,2.914247308/
      DATA HC/.03125,.046875,.0625/
      A(H,ER,F,B)=((1.18E10-F*4.*H*SQRT(ER))/(2.*F*SQRT(1.+.61*(ER-1.)*
     1 (B/H)**.1155)))
      F=1.E9
      ER=EC(3)
      DO 12 J=1,3
 20   FORMAT(/,*     A                 B*)
      PRINT 20
      H=HC(J)
      B=1.
      DO 10 I=1,51
      AL(I)=A(H,ER,F,B)
      BX(I)=B
      PRINT 2,AL(I),BX(I)
2     FORMAT(2(1PG20.5))
10    B=B+.15
      IF(J.LT.2) CALL CALCM1(51,BX,AL,0,1.0,8.5,3.48,3.75,12.5,9.0,
     119HMICROSTRIP ANTENNAS,-19,15HLENGTH B INCHES,15,
     2 15HLENGTH A INCHES,15,1,18)
      IF(J.EQ.2) CALL CALCM1(-51,BX,AL,-1)
      IF(J.EQ.3) CALL CALCM1(-51,BX,AL,-2)
      IF(J.GT.3) CALL CALCM1(-51,BX,AL,-5)
12    CONTINUE
      CALL GRID(0.,0.,.5,.5,25,18)
      CALL CALCM1(0,0.)
      END
```


MICROSTRIP ANTENNAS
F = 1 GHZ
εr = 2.55
H = 1/32
H = 3/64
H = 1/16
A = 2*B
A = B
A = B/2
LENGTH B INCHES
LENGTH A INCHES
1.000
1.600
2.200
2.800
3.400
4.000
4.600
5.200
5.800
6.400
7.000
7.600
8.200
8.800
3.750
3.720
3.690
3.660
3.630
3.600
3.570
3.540
3.510
3.480

```
      PROGRAM AOFER  (OUTPUT,TAPE6=OUTPUT)
      EXTERNAL FUN
      COMMON H,ER,F
      DIMENSION CONST(3),AL(51),BA(51),ATOB(1) ,A(14),ANS(1)
      NAMELIST /PARAM/H,F,ATOB
      DATA CONST/.03125,.046875,.0625/
      DATA A/1.,6.,1.E-1,1.E-6,1.E-4,.5,.5,1.E6,99.0,0.,1.,1.,.1,20./
      F=1.E9
      EINC=.144
      H=3./64.
      J=1
      ATOB(1)=1.
       ER=2.
      WRITE(6,1)
1     FORMAT(/)
      WRITE(6,PARAM)
      WRITE(6,2)
2     FORMAT(  5X,*ER*,10X,*A*,7X,*1/SQRT(ER)*)
3     FORMAT(3(F10.7))
      DO 10 I=1,51
       BA(I)=1./SQRT(ER)
      CALL ROOTER( FUN,A,ATOB,ANS)
      AL(I)=ANS(1) *ATOB(1)
      WRITE(6,3)ER,AL(I),BA(I)
10     ER=ER+EINC
      X1=.7071068
      X2=.3296902
      IF(J.LT.2) CALL CALCM1(51,BA,AL,0,X1 ,X2 ,1.5,4.2,12.0,9.0,19HMICR
     1OSTRIP ANTENNAS,-19,10H1/SQRT(ER),-9,15HLENGTH A INCHES,15,1,18)
      IF(J.EQ.2) CALL CALCM1(-51,BA,AL,-1)
      IF(J.EQ.3) CALL CALCM1(-51,BA,AL,-2)
      IF(J.GT.3) CALL CALCM1(-51,BA,AL,-5)
12    CONTINUE
      CALL GRID(0.,0.,.5,.5,24,18)
      CALL CALCM1(0,0.)
      END
      FUNCTION FUN(B,DUMY)
      COMMON H,ER,F
      DIMENSION DUMY(1)
      BN=B*DUMY(1)
      FUN=((1.18E10-F*4.*H*SQRT(ER))/(2.*F*SQRT(1.+.61*(ER-1.)*(B/H)**
     1.1155))) -BN
      RETURN
      END
```


MICROSTRIP ANTENNAS
1/SQRT(ER
LENGTH A INCHES
.3000
.3400
.3800
.4200
.4600
.5000
.5400
.5800
.6200
.6600
.7000
.7400
.7800
1.500
1.800
2.100
2.400
2.700
3.000
3.300
3.600
3.900
4.200

30

```
      PROGRAM AVSF (OUTPUT,INFUT)
C***THIS PROGRAM PLOTS AND PRINTS SAS VERSES FREQUENCY AT A SPECIFIED A/B RATIO
C***AND VARIOUS VALUES OF H.
C***INPUT DATA IS - ATOB,FMIN,FMAX,NP
C***NP=NUMBER OF FREQUENCIES (POINTS) TO BE CALCULATED.
C***  NOTE (FMAX-FMIN)/(NP-1) = CONVENIENT INCREMENT FOR THE FREQUENCY
C
      COMMON/B/A,B,F,H,ER
      DIMENSION HH(4),A1(51),A2(51),A3(51),A4(51),FX(51)
      DATA HH/.015,.031,.062,.125/
      DATA X1,X2,Y1,Y2,XL,YL/.1,10.,1.,10.,-28.,-9./
      MOD(I)=I-(I/4)*4
      HH(1)=.047
      ER=2.5
      READ*,ATOB,FMIN,FMAX,NP
      FINC=(FMAX-FMIN)/(NP-1)
      B=0.
      F=FMIN
      PRINT 1,ATOB,ER,HH(1),HH(2),HH(3),HH(4)
1     FORMAT(2X,*ATOB=*,F6.3,5X,*ER=*,F6.3,/,22X,4(19X,*H=*,F5.3),/,
     1 14X,*FREQ(GHZ)*,4(24X,*A*),/)
      DO 10 I=1,NP
      FX(I)=F*1.E-9
       H=HH(1)
      CALL LENGTH(ATOB,20)
      A1(I)=A
       H=HH(2)
      CALL LENGTH(ATOB,20)
      A2(I)=A
       H=HH(3)
      CALL LENGTH(ATOB,20)
      A3(I)=A
       H=HH(4)
      CALL LENGTH(ATOB,20)
      A4(I)=A
      PRINT 2,FX(I),A1(I),A2(I),A3(I),A4(I)
2     FORMAT(2X,5(1PG25.8))
      IF(MOD(I).EQ.0) PRINT 1425
1425  FORMAT(1H )
10    F=F+FINC
      CALL CALCM1(NP,FX,A1,0,X1,X2,Y1,Y2,XL,YL,
     119HMICROSTRIP ANTENNAS,-19,15HFREQUENCY (GHZ),-15
     2,15HLENGTH A INCHES,15,1,18)
      CALL LABLOG(28.,.1,10.,0.)
      CALL LABLOG(9.,1.,10.,90.)
      CALL GRID(0.,0.,14.,9.,-2,-1)
      CALL CALCM1(0,0.)
      END
```

STOP= 1.000 ER= 2.510

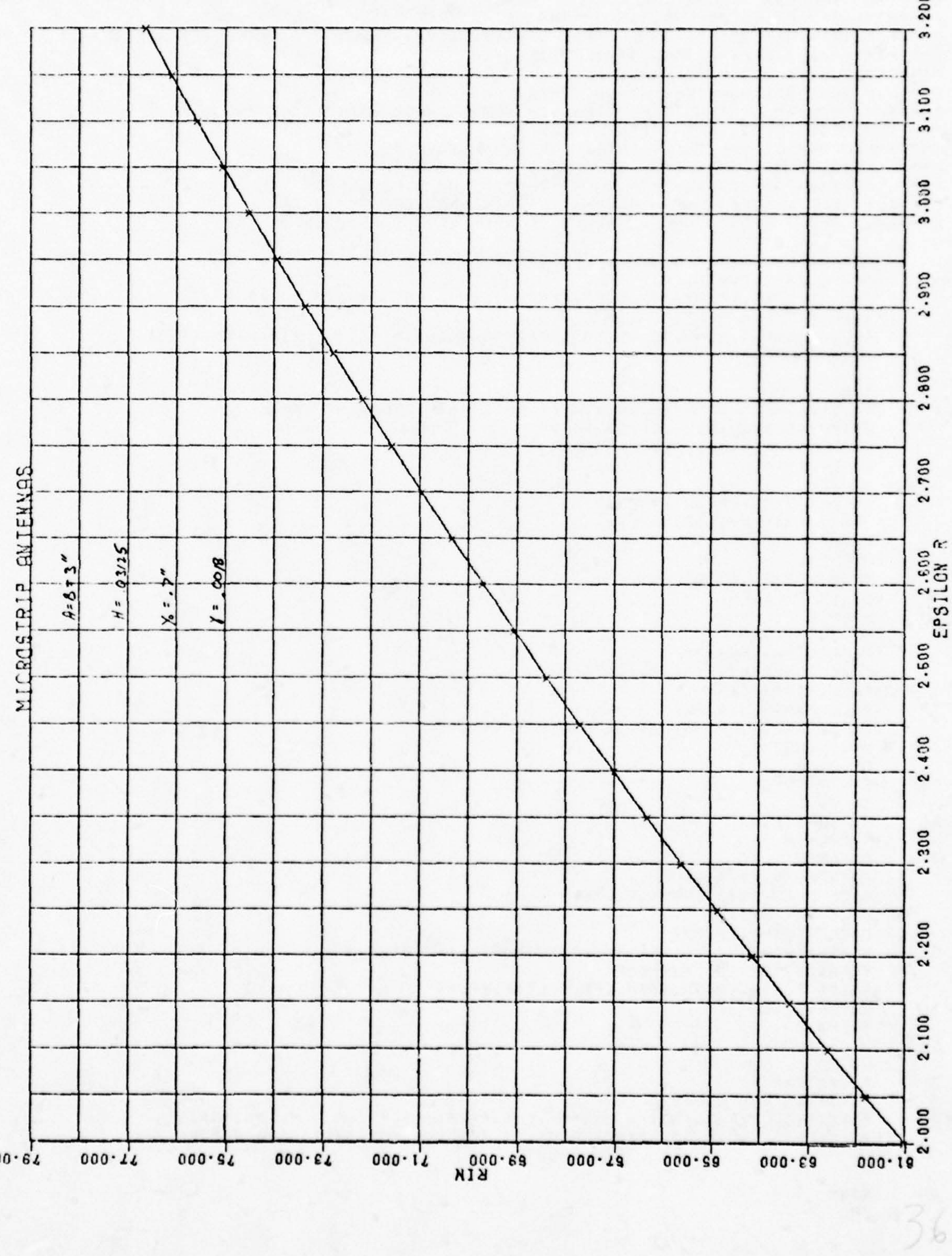
FREQ(GHZ)	H= .047 A	H= .031 A	H= .062 A	H= .125 A
.35000000	10.166015	10.046614	10.236671	10.364077
.45000000	7.9570491	7.8713763	8.0051871	8.0752253
.55000000	6.5395571	6.4757893	6.5733291	6.6067138
.65000001	5.5515916	5.5023303	5.5753838	5.5832306
.75000000	4.8229603	4.7846666	4.8394338	4.8285805
.85000000	4.2630605	4.2331608	4.2739163	4.2486579
.95000000	3.8191404	3.7958787	3.8255505	3.7988719
1.0500000	3.4584036	3.4405247	3.4612061	3.4152436
1.1500000	3.1593766	3.1459519	3.1591317	3.1055267
1.2500000	2.9074051	2.8977283	2.9047045	2.8445413
1.3500000	2.6921435	2.6856648	2.6872947	2.6215717
1.4500000	2.5060781	2.5023912	2.4993729	2.4283354
1.5500000	2.3436191	2.3423116	2.3352928	2.2605433
1.6500000	2.2005208	2.2013345	2.1907664	2.1122985
1.7500000	2.0735006	2.0761962	2.0624779	1.9807014
1.8500000	1.9599796	1.9643567	1.9478229	1.8630818
1.9500000	1.8579039	1.8637927	1.8447269	1.7573127
2.0500000	1.7656170	1.7728724	1.7515169	1.6615789
2.1500000	1.6817682	1.6902653	1.6668285	1.5747818
2.2500000	1.6052448	1.6148753	1.5895382	1.4954692
2.3500000	1.5351220	1.5457913	1.5187120	1.4227839
2.4500000	1.4706250	1.4822493	1.4535671	1.3559232
2.5500000	1.4110991	1.4236064	1.3934426	1.2942096
2.6500000	1.3559879	1.3693125	1.3377764	1.2370670
2.7500000	1.3048152	1.3188991	1.2860878	1.1840023
2.8500000	1.2571711	1.2719622	1.2379625	1.1345911
2.9500000	1.2127008	1.2281524	1.1930425	1.0884660
3.0500000	1.1710955	1.1871656	1.1510158	1.0453076
3.1500000	1.1320856	1.1487359	1.1116102	1.0048364
3.2500000	1.0954341	1.1126300	1.0745862	.96680730
3.3500000	1.0609323	1.0786421	1.0397332	.93100406
3.4500000	1.0283957	1.0465902	1.0068644	.89723535
3.5500000	.99765901	1.0163125	.97581409	.86533121

```
      PROGRAM DRIVE(INPUT,OUTPUT)
C                    THIS PROGRAM PRODUCES PLOTS OF R-INPUT,EFFICIENCY,AND
C                    BANDWIDTH VERSUS THE PARAMETER CHOSEN BY ≠OPT≠
C     OPT=0 FOR PLOTS .VS. A/B RATIO  AND INPUT DATA IS.
C     F, H, ER, XYO, LOSSTAN, ABMIN, ABMAX, NPOINTS.
C     OPT=1 FOR PLOTS VS. FREQUENCY  AND INPUT DATA IS
C     A/B, XYO, H, ER, LOSSTAN, FMIN, FMAX, NPOINTS
C     OPT=2 FOR PLOTS .VS. ER  AND INPUT DATA IS.
C     F, H, A/B, XYO, LOSSTAN, ERMIN, ERMAX, NPOINTS.
C     OPT=3  FOR PLOTS .VS. ER  AND INPUT DATA IS.
C     A, B, YO, LOSSTAN, ERMIN, ERMAX, NPOINTS.
      REAL LAMDA,LAMDAG,L,LOSSTAN,IM
      COMMON/B/A,B,F,H,ER
      COMMON/E/RS,RC,PI2,IM,L,PI,LAMDAG,LAMDA,LOSSTAN,ZO,PA,PB,P
      COMMON/F/EFF,DELTAF,GAIN
      DIMENSION X(150),Y(150),D(150),E(150)
      DATA FREQ/9HFREQUENCY/,ABR/9HA/B RATIO/,EER/9HEPSILON R/
      DATA IM,ABINC,FINC,ERINC,Y1,Y2,XL,YL/1.,0.,0.,0.,0.,0.,12.0,9.0/
      DATA TANG/9HLOSS TANG/
      FREQU(H,ER,A,B)=5.901427165E9/(A*SQRT(1.+.61*(ER-1)*(B/H)**.1155)
     1+2.*H*SQRT(ER))
      MOD(I)=I-(I/4)*4
      CALL ANGL
4     READ*,NT
1     READ*,OPT
       IF(OPT.EQ.-100) GO TO 4
      ABINC=0.
      FINC=0.
      ERINC=0.
      IF(OPT.EQ.1) GO TO 5
      IF(OPT.EQ.2.) GO TO 15
      IF(OPT.EQ.3.)GO TO 20
       IF(OPT.LT.0.) GO TO 120
      READ*,F,H,ER,XYO,LOSSTAN,ABMIN,ABMAX,NPOINTS
      NAMELIST/OPT0/F,H,ER,LOSSTAN,XYO ,NT
      AX=ABR
      X1=ABMIN
      X2=ABMAX
      ABINC=(X2-X1)/NPOINTS
      ATOB=X1
      B=5.75E9/(F*ATOB*SQRT(ER))
      PRINT OPT0
       GO TO 400
5     READ*,ATOB,XYO,H,ER,LOSSTAN,FMIN,FMAX,NPOINTS
      AX=FREQ
      X1=FMIN
      X2=FMAX
      FINC=(X2-X1)/NPOINTS
      F=X1
      B=5.75E9/(F*ATOB*SQRT(ER))
      NAMELIST/OPT1/ATOB,XYO,H,ER,LOSSTAN,NT
      PRINT OPT1
      GO TO 400
15    READ*,F,H,ATOB,XYO,LOSSTAN,ERMIN,ERMAX,NPOINTS
      AX=EER
      X1=ERMIN
      X2=ERMAX
      ER=X1
      B=5.75E9/(F*ATOB*SQRT(ER))
      ERINC=(X2-X1)/NPOINTS
      NAMELIST/OPT2/F,H,ATOB,XYO,LOSSTAN,NT
      PRINT OPT2
      GO TO 400
20    READ*,A,B,H,YO,LOSSTAN,ERMIN,ERMAX,NPOINTS
```

```
      ATOB=A/B
      AX=EFR
      X1=ERMIN
      X2=ERMAX
      ER=X1
      ERINC=(X2-X1)/NPOINTS
      NAMELIST/OPT3/A,B,H,LOSSTAN, YO,NT
      PRINT OPT3
400   N=NPOINTS+1
456   FORMAT(/,10X,*A*,14X,*A/B*,15X,*F*,14X,*ER*, 9X,*DELTA F*, 6X,
     1*EFFICIENCY*,11X,*    ZO   *,  8X,*R INPUT*,/)
      PRINT 456
      DO 100 I=1,N
      IF(OPT.EQ.3.) F=FREQU(H,ER,A,B)
      IF(OPT.EQ.3.) GO TO 10
      CALL LENGTH(ATOB,20)
      YO= A/XYO
10    CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(NT,W)
      CALL RIN(-1.,W,RH)
      E(I)=EFF
      D(I)=DELTAF
      FG=F*1.E-9
      FIX=(4.131666667E-3/H+1.5822-H*7.466026667)/(FG**(.32814+2.7515*H+
     1 6.9077*H*H))
      RI=RH*SIN(YC*P)**2 *FIX
      Y(I)=RI
      X(I)=ER
      IF(OPT.EQ.1.) X(I)=F
      IF(OPT.EQ.0.) X(I)=ATOB
789   FORMAT(8(1PG16.5))
      PRINT 789,A,ATOB,F,ER,D(I),E(I),ZO,Y(I)
      IF(MOD(I).EQ.0) PRINT 2
2     FORMAT(1H )
      F=F+FINC
      ER=ER+ERINC
100   ATOB=ATOB+ABINC
       CALL CALCM1(N ,X,Y,-1,X1,X2,Y1,Y2,XL,YL,19HMICROSTRIP ANTENNAS,
     1 -19,AX          ,-9,3HRIN,3,1,18)
      CALL GRID(0.,0.,.5,.5,24,18)
      CALL CALCM1(0,0.)
      GO TO 1
       CALL CALCM1(N ,X,D,-1,X1,X2,Y1,Y2,XL,YL,19HMICROSTRIP ANTENNAS,
     1 -19,AX          ,-9,7HDELTA F,7,1,18)
      CALL GRID(0.,0.,.5,.5,24,18)
       CALL CALCM1(N ,X,E,-1,X1,X2,Y1,Y2,XL,YL,19HMICROSTRIP ANTENNAS,
     1 -19,AX          ,-9,10HEFFICIENCY,10,1,18)
      CALL GRID(0.,0.,.5,.5,24,18)
120   STOP
      END
```

```
$OPT3
A       = .3E+01,
B       = .2E+01,
H       = .3125E-01,
LOSSTAN = .18E-02,
YO      = .53E+00,
NT      = 1,
$END
```

A	A/H	F	EP	DELTA F	EFFICIENCY	ZO	R INPUT
3.0000	1.5000	1.36724E+09	2.0000	3.94393E+07	.85571	3.9604	61.108
3.0000	1.5000	1.35057E+09	2.0500	3.81395E+07	.85230	3.9121	61.852
3.0000	1.5000	1.33450E+09	2.1000	3.70106E+07	.84891	3.8656	62.581
3.0000	1.5000	1.31900E+09	2.1500	3.58371E+07	.84554	3.8207	63.295
3.0000	1.5000	1.30401E+09	2.2000	3.48439E+07	.84218	3.7773	63.994
3.0000	1.5000	1.28957E+09	2.2500	3.38466E+07	.83883	3.7354	64.679
3.0000	1.5000	1.27552E+09	2.3000	3.29010E+07	.83550	3.6949	65.349
3.0000	1.5000	1.26196E+09	2.3500	3.20035E+07	.83218	3.6556	66.006
3.0000	1.5000	1.24882E+09	2.4000	3.11506E+07	.82888	3.6176	66.650
3.0000	1.5000	1.23609E+09	2.4500	3.03392E+07	.82559	3.5807	67.280
3.0000	1.5000	1.22373E+09	2.5000	2.95667E+07	.82232	3.5450	67.897
3.0000	1.5000	1.21174E+09	2.5500	2.88303E+07	.81907	3.5103	68.502
3.0000	1.5000	1.20009E+09	2.6000	2.81277E+07	.81583	3.4766	69.095
3.0000	1.5000	1.18878E+09	2.6500	2.74568E+07	.81261	3.4439	69.675
3.0000	1.5000	1.17777E+09	2.7000	2.68156E+07	.80940	3.4121	70.244
3.0000	1.5000	1.16707E+09	2.7500	2.62022E+07	.80621	3.3811	70.801
3.0000	1.5000	1.15666E+09	2.8000	2.56150E+07	.80303	3.3510	71.347
3.0000	1.5000	1.14651E+09	2.8500	2.50524E+07	.79987	3.3217	71.882
3.0000	1.5000	1.13663E+09	2.9000	2.45130E+07	.79673	3.2931	72.406
3.0000	1.5000	1.12701E+09	2.9500	2.39954E+07	.79360	3.2653	72.920
3.0000	1.5000	1.11762E+09	3.0000	2.34984E+07	.79049	3.2382	73.423
3.0000	1.5000	1.10846E+09	3.0500	2.30209E+07	.78739	3.2117	73.917
3.0000	1.5000	1.09952E+09	3.1000	2.25618E+07	.78431	3.1859	74.400
3.0000	1.5000	1.09080E+09	3.1500	2.21201E+07	.78125	3.1607	74.874
3.0000	1.5000	1.08228E+09	3.2000	2.16949E+07	.77820	3.1360	75.338


MICROSTRIP ANTENNAS
EPSILON R
RIN
2.000
2.100
2.200
2.300
2.400
2.500
2.600
2.700
2.800
2.900
3.000
3.100
3.200
61.000
63.000
65.000
67.000
69.000
71.000
73.000
75.000
77.000
79.000

```
      PROGRAM EANDH(INPUT,OUTPUT)
C***BASED ON MOE KALOISS PAPER ON MICROSTRIP ANTENNAS 1975
C***THIS PROGRAM  SHOWS HOW CURCUIT BOARD TOERANCES, VARIATIONS IN ER AND H,
C***WILL EFFECT THE OPERATION OF THE MICROSTRIP PATCH   OUTPUT DATA IS
C***FREQ(F)--HEIGHT(H)--DIELECTRIC CONSTANT(ER)--INPUT RESISTANCE(RI)--GAIN--
C***EFFICIENCY(EFF)--BANDWIDTH(DELTAF)--ZO
C***INPUT DATA IS AS FOLLOWS.
C***A,B,YO,LOSSTAN,HMIN,HMAX,NH,ERMIN,ERMAX,NE,KK
C***THE PROGRAM CONTINUES READING NEW INPUT CARDS UNTIL NONE ARE LEFT
C***NH-NUMBER OF VALUES (POINTS) FOR H
C***NE-NUMBER OF VALUES (POINTS) FOR ER TO TAKE ON.
C***  NOTE. (HMAX-HMIN)/(NH-1) =CONVIENIENT INCREMENT FOR H
C***  (ERMAX-ERMIN)/(NE-1) = CONVENIENT  INCREMENT FOR ER
C***KK=1 FOR A SERIES OF H VALUES BETWEEN EACH CHANGE IN ER
C***KK=2 FOR A SERIES OF ER VALUES BETWEEN EACH CHANGE IN H.
C
      REAL K,LAMDA,LAMDAG,MU,L,LOSSTAN,IM
      COMMON/B/A,B,F,H,ER
      COMMON/E/RS,RC,PI2,IM,L,PI,LAMDAG,LAMDA,LOSSTAN,ZO,PA,PB,P
      COMMON/F/EFF,DELTAF,GAIN
      FREQU(H,ER,A,B)=5.901427165E9/(A*SQRT(1.+.61*(ER-1)*(B/H)**.1155)
     1+2.*H*SQRT(ER))
      IM=1.
      CALL ANGL
1     READ*,A,B,YO,LOSSTAN,HMIN,HMAX,NH ,ERMIN,ERMAX,NE ,KK
      IF(EOF(5LINPUT).NE.0) GO TO 99
      NAMELIST/PARAM/A,B,YO,LOSSTAN
      ER=ERMIN
      H=HMIN
      EINC=(ERMAX-ERMIN)/(NE-1)
      HINC=(HMAX-HMIN)/(NH-1)
      PRINT PARAM
      PRINT 4
      IF(KK.EQ.2) GO TO 40
      DO 10 I=1,NE
      H=HMIN
      DO 20 J=1,NH
      F=FREQU(H,ER,A,B)
      CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(1,W)
      CALL RIN(-1.,W,RH)
      PRINT 3,F,H,ER,RH,GAIN,EFF,DELTAF,YR,YE
20    H=H+HINC
      PRINT 2
10    ER=ER+EINC
      GO TO 1
40    DO 50 I=1,NH
      ER=ERMIN
      DO 60 J=1,NE
      F=FREQU(H,ER,A,B)
      CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(1,W)
      CALL RIN(-1.,W,RH)
      YE=RH*(SIN((YO+.01)*P)**2-SIN((YO-.01)*P)**2)
      YR=ASIN(SQRT(50./RH))/P
      PRINT 3,F,H,ER,RH,GAIN,EFF,DELTAF,YR,YE
60    ER=ER+EINC
      PRINT 2
50    H=H+HINC
      GO TO 1
2     FORMAT(1H )
3     FORMAT(9(1PG14.5))
4     FORMAT(3X,*FREQUENCY*, 9X,*H*,11X,*ER*,11X,*   R   *, 8X,*GAIN*,
     18X,*EFFICIENCY*,5X,*BANDWIDTH*,3X,*50 OHM YO*,3X,*.01## ERROR*,//)

99    STOP
      END
```

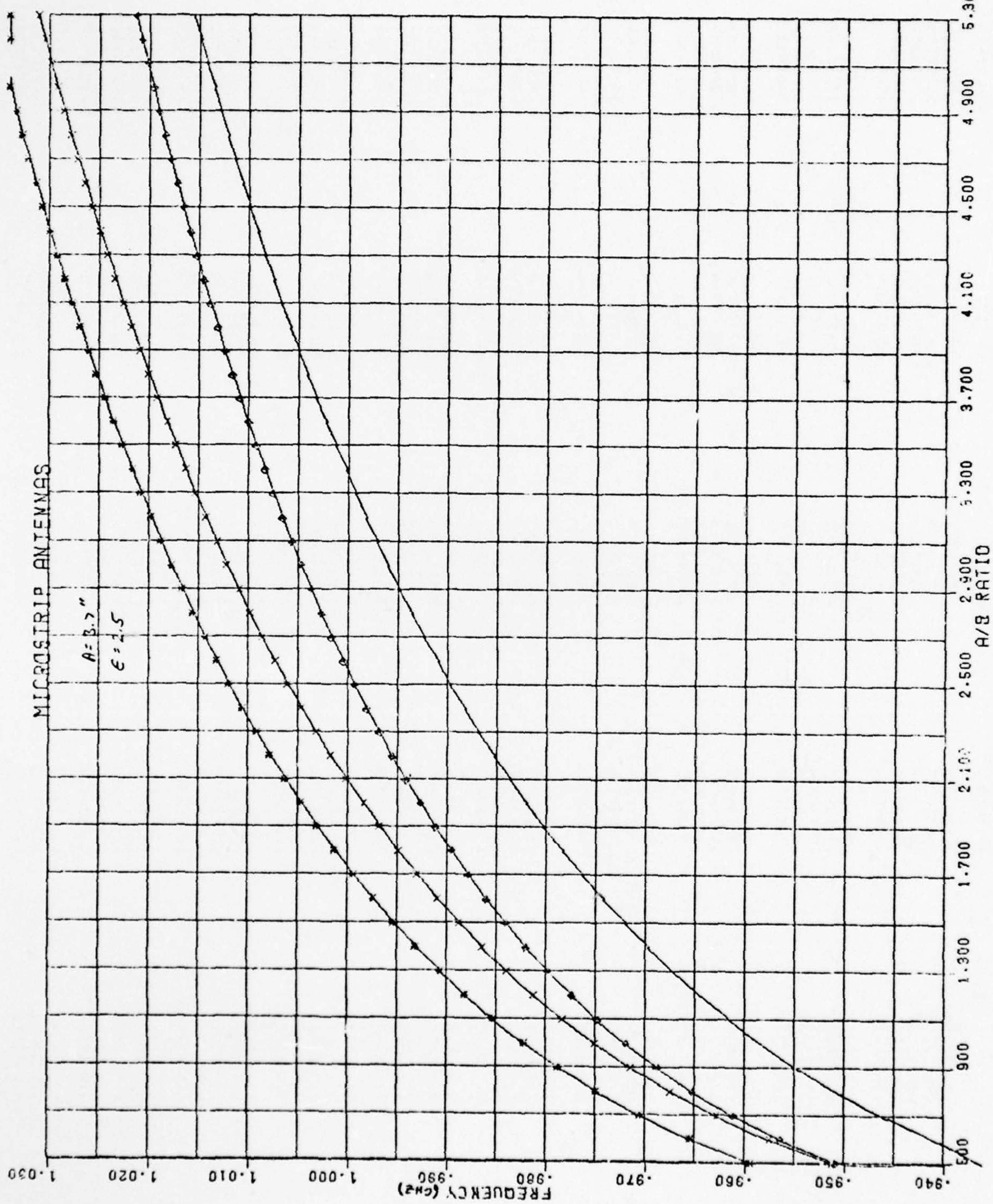
```
$PARAM
A       = .1E+02,
B       = .6E+01,
YO      = .5E+01,
LOSSTAN = .1E-03,
$END
```

FREQUENCY	H	ER	R	GAIN	EFFICIENCY	BANDWIDTH	50 OHM YO	.01** ERROR
3.87840E+08	3.12500E-02	2.1500	58.365	4.6739	.82653	9.56321E+06	3.7802	4.86989E-0
3.83181E+08	3.12500E-02	2.2000	58.567	4.6484	.82238	9.27603E+06	3.7665	4.83043E-0
3.78685E+08	3.12500E-02	2.2500	58.756	4.6230	.81824	9.00488E+06	3.7540	4.79229E-0
3.94041E+08	6.25000E-02	2.1500	129.99	5.0700	.90424	9.24742E+06	2.1476	2.15034E-0
3.89471E+08	6.25000E-02	2.2000	130.82	5.0545	.90179	8.95919E+06	2.1393	2.13077E-0
3.85056E+08	6.25000E-02	2.2500	131.63	5.0392	.89934	8.68666E+06	2.1314	2.12327E-0
3.96511E+08	9.37500E-02	2.1500	200.17	5.2079	.93280	9.21907E+06	1.6872	4.92454E-0
3.92007E+08	9.37500E-02	2.2000	201.66	5.1960	.93106	8.92978E+06	1.6800	4.30596E-0
3.87654E+08	9.37500E-02	2.2500	203.12	5.1843	.92931	8.65601E+06	1.6732	4.88754E-0
3.97466E+08	.12500	2.1500	268.68	5.2777	.94758	9.22809E+06	1.4440	8.73768E-0
3.93019E+08	.12500	2.2000	270.82	5.2677	.94621	8.93828E+06	1.4376	8.71305E-0
3.88718E+08	.12500	2.2500	272.92	5.2579	.94483	8.66387E+06	1.4314	8.68273E-0

```
      PROGRAM FVSATOB (OUTPUT,INPUT)
C***THIS PROGRAM PLOTS AND PRINTS THE RESONANT FREQUENCY VERSES A/B RATIO
C***FOR A FIXED VALUE OF A AND VARIOUS VALUES OF H.
C***INPUT DATA IS AS FOLLOWS.
C***A,ER,ABMIN,ABMAX,NP,Y1,Y2
C***NP=NUMBER OF A/B RATIOS (POINTS) TO BE CALCULATED AND PLOTTED
C***  NOTE. (ABMAX-ABMIN)/(NP-1) = CONVENIENT INCREMENT FOR THE A/B RATIO POINTS
C
      DIMENSION X(51),F1(51),F2(51),F3(51),F4(51)
      DATA H1,H2,H3,H4/.015,.031,.062,.125/
      MOD(I)=I-(I/5)*5
      FREQU(H,ER,A,B)=5.901427165E9/(A*SQRT(1.+.61*(ER-1)*(B/H)**.1155)+
     1 2.*H*SQRT(ER))
100   READ*,A,ER,ABMIN,ABMAX,NP,Y1,Y2
      IF(EOF(5LINPUT).NE.0) GO TO 999
      PRINT 1,A,ER,H1,H2,H3,H4
1     FORMAT(10X,*A=*,F6.3,5X,*ER=*,F6.3,//,16X,*ATOB*,3X,4(16X
     1 ,*FREQ(GHZ)*),/,21X,4(18X,*H=*,F5.3),/)
      AINC=(ABMAX-ABMIN)/(NP-1)
      ATOB=ABMIN
      DO 10 I=1,NP
      B=A/ATOB
      X(I)=ATOB
      F1(I)=FREQU(H1,ER,A,B)*1.E-9
      F2(I)=FREQU(H2,ER,A,B)*1.E-9
      F3(I)=FREQU(H3,ER,A,B)*1.E-9
      F4(I)=FREQU(H4,ER,A,B)*1.E-9
      PRINT 2,X(I),F1(I),F2(I),F3(I),F4(I)
2     FORMAT(2X,5(1PG25.8))
      IF(MOD(I).EQ.0) PRINT 1425
1425  FORMAT(1H )
10    ATOB=ATOB+AINC
      CALL CALCM1(NP,X,F1,0,ABMIN,ABMAX,Y1,Y2,12. ,9.,
     1 19HMICROSTRIP ANTENNAS,-19,9HA/B RATIO,9,9HFREQUENCY,9,1,18)
      CALL CALCM1(-NP,X,F2,-1)
      CALL CALCM1(-NP,X,F3,-2)
      CALL CALCM1(-NP,X,F4,-5)
      CALL GRID(0. ,0.,.5,.5,24,18)
      CALL CALCM1(0,0.)
      GO TO 100
999   STOP
      END
```

A= 3.700 ER= 2.500

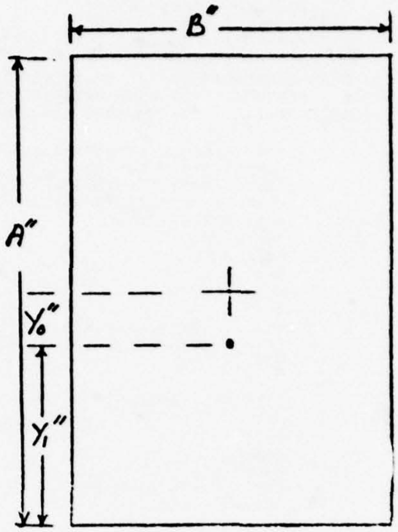
ATOR	FREQ(GHZ) H= .015	FREQ(GHZ) H= .031	FREQ(GHZ) H= .062	FREQ(GHZ) H= .125
.50000000	.93397268	.95144226	.95954692	.95099301
.60000000	.94033328	.95767559	.96554457	.95655769
.70000000	.94570756	.96293884	.97060509	.96124857
.80000000	.95035988	.96749244	.97498054	.96530122
.90000000	.95446091	.97150435	.97883335	.96886735
1.0000000	.95812684	.97503922	.98227438	.97205036
1.1000000	.96144107	.97832477	.98538257	.97492392
1.2000000	.96446488	.98123336	.98821621	.97754234
1.3000000	.96724485	.98399879	.99081951	.97994692
1.4000000	.96981720	.98651065	.99322684	.98216334
1.5000000	.97221067	.98884715	.99546538	.98423523
1.6000000	.97444837	.99103101	.99755708	.98616489
1.7000000	.97654926	.99309083	.99951984	.98797498
1.8000000	.97852931	.99501199	1.0013685	.98967929
1.9000000	.98040074	.99683738	1.0031155	.99128937
2.0000000	.98217557	.99855790	1.0047713	.99281497
2.1000000	.98386299	1.0002129	1.0063448	.99426441
2.2000000	.98547114	1.0017802	1.0078439	.99564484
2.3000000	.98700710	1.0032770	1.0092751	.99696246
2.4000000	.98847702	1.0047091	1.0106442	.99822257
2.5000000	.98988631	1.0060819	1.0119565	.99943019
2.6000000	.99123975	1.0074001	1.0132162	1.0005892
2.7000000	.99254157	1.0086679	1.0144275	1.0017034
2.8000000	.99379552	1.0098888	1.0155940	1.0027761
2.9000000	.99500498	1.0110663	1.0167187	1.0038102
3.0000000	.99617293	1.0122032	1.0178045	1.0048084
3.1000000	.99730225	1.0133023	1.0188541	1.0057730
3.2000000	.99839525	1.0143659	1.0198696	1.0067062
3.3000000	.99945422	1.0153963	1.0208532	1.0076100
3.4000000	1.0004812	1.0163954	1.0218069	1.0084861
3.5000000	1.0014781	1.0173651	1.0227324	1.0093361
3.6000000	1.0024465	1.0183071	1.0236313	1.0101616
3.7000000	1.0033881	1.0192228	1.0245050	1.0109639
3.8000000	1.0043042	1.0201137	1.0253550	1.0117442
3.9000000	1.0051963	1.0209811	1.0261824	1.0125037
4.0000000	1.0060655	1.0218262	1.0269884	1.0132434
4.1000000	1.0069129	1.0226500	1.0277741	1.0139645
4.2000000	1.0077397	1.0234536	1.0285405	1.0146676
4.3000000	1.0085469	1.0242381	1.0292884	1.0153538
4.4000000	1.0093350	1.0250041	1.0300188	1.0160238
4.5000000	1.0101054	1.0257527	1.0307324	1.0166783
4.6000000	1.0108585	1.0264845	1.0314300	1.0173181
4.7000000	1.0115953	1.0272003	1.0321122	1.0179437
4.8000000	1.0123163	1.0279008	1.0327798	1.0185558
4.9000000	1.0130222	1.0285866	1.0334333	1.0191549
5.0000000	1.0137137	1.0292582	1.0340733	1.0197415
5.1000000	1.0143913	1.0299164	1.0347004	1.0203163
5.2000000	1.0150556	1.0305616	1.0353149	1.0208795


MICROSTRIP ANTENNAS
A=3.7"
ε=2.5
FREQUENCY (GHz)
1.030
1.020
1.010
1.000
.990
.980
.970
.960
.950
.940
A/B RATIO
500
900
1.300
1.700
2.100
2.500
2.900
3.300
3.700
4.100
4.500
4.900
5.300

```
      PROGRAM MICROAN(INPUT,OUTPUT)
C  THIS PROGRAM DESIGNS A BACK FED MICROSTRIP ANTENNA.
C  INPUT DATA IS AS FOLLOWS.
C  DESIRED FREQUENCY IN MHZ
C  A/B RATIO
C  SUBSTRATE HEIGHT IN INCHES
C  DIELECTRIC CONSTANT
C  DESIRED INPUT IMPEDANCE
C  MEASURED/CALCULATED INPUT RESISTANCE FOR A TEST ANTENNA (HOPEFULLY 1.0)
C  LOSS TANGENT.
C  THE PROGRAM IS SET UP TO RUN ON BOTH HIGH SPEED LINE PRINTERS AS WELL AS
C  TELETYPE.  FOR LINE PRINTER USE, THE FIRST FREQUENCY READ IN SHOULD BE
C  NEGATIVE.  THE PROGRAM CONTINUES READING UNTIL IT RUNS OUT OF DATA CARDS.
C
      REAL K,LAMDA,LAMDAG,MU,L,LOSSTAN,IM
      COMMON/B/A,B,F,H,ER
      COMMON/E/RS,RC,PI2,IM,L,PI,LAMDAG,LAMDA,LOSSTAN,ZO,PA,PB,P
      COMMON/F/EFF,DELTAF,GAIN
      MOD(I)=I-(I/4)*4
      IM=1.
      CALL ANGL
      N=0
      PRINT 60
      I=0
1     READ*,F,ATOB,H,ER,RDS,X,LOSSTAN
      IF(EOF(5LINPUT).NE.0) GO TO 99
      I=I+1
      FG=F
      IF(F.GT.0.) GO TO 10
      N=1
      PRINT 40
      FG=-FG
10    F=FG*1.E9
      CALL LENGTH(ATOB,20)
      YO=A/3.
      H=H+.001
      CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(1,W)
      CALL RIN(-1.,W,RH)
      FIX=(4.13166667E-3/H+1.5822-H*7.+66026667)/(FG**(.32814+2.7515*H+
     1 6.9077*H*H))
      P1=P
      RH1=RH*FIX*X
      H=H-.001
      CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(1,W)
      CALL RIN(-1.,W,RH)
      FIX=(4.13166667E-3/H+1.5822-H*7.466026667)/(FG**(.32814+2.7515*H+
     1 6.9077*H*H))
      RH=RH*FIX *X
      YO=A/2.
      ZPO=SQRT(RDS/RH)
      IF(ZPO.GT.1.) RDS=RH*(SIN(YO*P)**2)
      IF(ZPO.LT.1.) YO=ASIN(ZPO)/P
      Y1=A/2.-YO
      YOER=RDS-RH*SIN((YO-.01)*P)**2
      HER=RH1*(SIN(YO*P1)**2)-RDS
      DELTAF=DELTAF*1.E-9
      IF(N.LT.1)PRINT 80,A,B,YO,Y1,YOER,HER,DELTAF,GAIN,RDS,FG,ATOB,H
     1,ER,LOSSTAN,X,RH ,P
      IF(N.GT.0) PRINT 30,A,B,HER,H,ER,FG,RDS,Y1,RH,YOER,LOSSTAN,X,
     1 DELTAF, GAIN,EFF
      IF(N.LT.1) PRINT 70
      IF(MOD(I).EQ.0) PRINT 50


      GO TO 1
30    FORMAT(15(1X,F8.4))
40    FORMAT(*1   A*,8X,*B*,6X,*H ERROR*,5X,*H*,6X,*ER*,9X,*F*,6X,*RDS*,
     17X,*Y1*,7X,*RO*,8X,*YO ERROR*,3X,*LOSSTAN*,3X,*X*,3X,*BANDWIDTH *,
     1*GAIN(DB)*,3X,*EFF*)
50    FORMAT(* *)
60    FORMAT(* TYPE IN THE FOLLOWING PARAMETERS.*,/,* FREQ IN GHZ*,/,
     1* A/B RATIO*,/,* HEIGHT IN INCHES*,/,* DIELECTRIC CONSTANT*,/,
     2* DESIRED INPUT RESISTANCE*,/,* CORRECTION FACTOR = MEASURED/*,
     3*CALCULATED INPUT RESISTANCE OF A TEST ANTENNA*,/,
     4* LOSS TANGENT*)
70    FORMAT(*  IF YOU HAVE NO MORE DATA TYPE IN ≠STOP≠*)
80    FORMAT(* LENGTH A*,T30,*=*,F12.6,/,* WIDTH B*,T30,*=*,F12.6,
     1/,* YO*,T30,*=*,F12.6,/,* Y1=A/2 - YO*,T30,*=*,F12.6,/,
     2* OHMS PER .01≡  CHANGE IN YO*,T30,*=*,F12.6,/,
     3* OHMS PER .001≠≠ CHANGE IN H*,T30,*=*,F12.6 ,/,
     4* -3DB BANDWIDTH (GHZ)*,T30,*=*,F12.6,/,* GAIN (DB OVER ISOTROPIC)
     5*,T30,*=*,F12.6,/,* INPUT RESISTANCE*,T30,*=*,F12.6,/,
     6* FREQUENCY IN GHZ*,T30,*=*,F12.6,/,* A/B RATIO*,T30,*=*,F12.6,/,
     7* SUBSTRATE HEIGHT *,T30,*=*,F12.6,/,* DIELECTRIC CONSTANT*
     8,T30,*=*,F12.6,/,* LOSS TANGENT*,T30,*=*,F12.6,/,* CORRECTION *
     9*FACTOR*,T30,*=*,F12.6,/,* RO*,T30,*=*,F12.6,/,* P*,T30,*=*,F12.6)
99      STOP
      END
```

**Program to Design Microstrip Antennas
With a Back Feed**

By: John W. McCorkle.

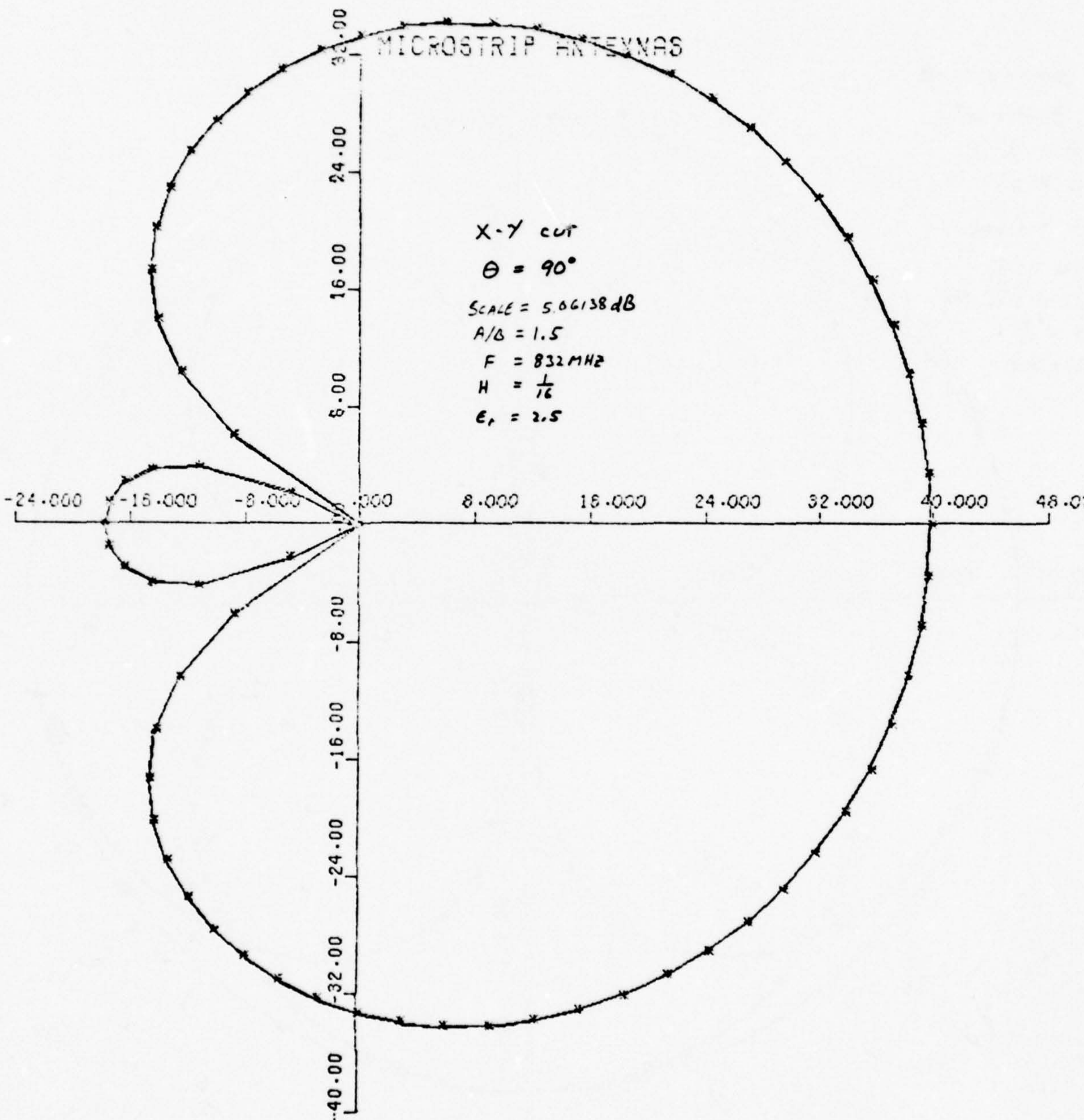



```
 75/12/12. 10.25.24.
WHITE OAK 6500/397
USER NUMBER:   685,
TERMINAL:          53,TTY
RECOVER /SYSTEM:BATCH
$RFL,20000.
/RFL,40000
RFL,40000.
/GET,MICROAN/UN=685.
/GET,LIB=SUBS/UN=685.
/LINK,F=MICROAN,P=LIB,X.
 TYPE IN THE FOLLOWING PARAMETERS.
 FREQ IN GHZ
 A/B RATIO
 HEIGHT IN INCHES
 DIELECTRIC CONSTANT
 DESIRED INPUT RESTANCE
 CORRECTION FACTOR (USUALLY 1.0)
 LOSS TANGENT
? 1.2 1.25 .125 2.5 50. 1. .0005
 LENGTH A                         =      2.990736
 WIDTH B                          =      2.392589
 YO                               =       .383353
 YI=A/2 - YO                      =      1.112014
 OHMS PER .01"  CHANGE IN YO      =      2.479940
 OHMS PER .001'' CHANGE IN H      =      -.295700
 -3DB BANDWIDTH (GHZ)             =       .028777
 GAIN (DB)                        =      5.294947
 INPUT RESISTANCE                 =     50.000000
 FREQUENCY (GHZ)                  =      1.200000
 A/B RATIO                        =      1.250000
 SUBSTRATE HEIGHT H               =       .125000
 DIELECTRIC CONSTANT              =      2.500000
 LOSS TANGENT                     =       .000500
 CORRECTION FACTOR                =      1.000000
 RH                               =    358.968443
 P                                =       .997695
  IF YOU HAVE NO MORE DATA TYPE IN 'STOP'
? 3. 1.1 .047 2.5 50. 1. .001
 LENGTH A                         =      1.195178
 WIDTH B                          =      1.086526
 YO                               =       .149638
 YI=A/2 - YO                      =       .447951
 OHMS PER .01"  CHANGE IN YO      =      6.364403
 OHMS PER .001'' CHANGE IN H      =       .336172
 -3DB BANDWIDTH (GHZ)             =       .077330
 GAIN (DB)                        =      5.150947
 INPUT RESISTANCE                 =     50.000000
 FREQUENCY (GHZ)                  =      3.000000
 A/B RATIO                        =      1.100000
 SUBSTRATE HEIGHT H               =       .047000
 DIELECTRIC CONSTANT              =      2.500000
 LOSS TANGENT                     =       .001000
 CORRECTION FACTOR                =      1.000000
 RH                               =    373.280478
 P                                =      2.504001
  IF YOU HAVE NO MORE DATA TYPE IN 'STOP'
? STOP

 *TERMINATED*

/COST.
APPROX COST OF RUN IS $     .57
RETURN(ZZZZCO)
/BYE

685        LOG OFF.  10.31.46.
685        CP        3.884 SEC.
```

```
      PROGRAM PATTERN(INPUT,OUTPUT)
C**THIS PROGRAM PRODUCES PATTERN PLOTS OF THE X-Y AXIS PLANE, THE X-Y PLANE
C** OFF THE EDGE OF THE ANTENNA, THE Z-X AXIS PLANE, AND THE Z-Y AXIS PLANE.
C**INPUT DATA IS AS FOLLOWS.
C  A/B RATIO, FREQ IN HZ, H IN INCHES, ER, XYO WHERE YO=A/XYO, AND LOSSTANGENT.
      REAL LAMDA,LAMDAG,L,LOSSTAN,IM
      COMMON/B/A,B,F,H,ER
      COMMON/E/RS,RC,PI2,IM,L,PI,LAMDAG,LAMDA,LOSSTAN,ZO,PA,PB,P
      COMMON/G/PATK,XY,ZYX
      DATA XY,ZYX/2HXY,3HZYX/
      CALL ANGL
      IM=1.
10    READ*,ATOB,F,H,ER,XYO,LOSSTAN
      IF(EOF(5LINPUT).NE.0) GO TO 99
      CALL LENGTH(ATOB,20)
      YO=A/XYO
      CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(1,W)
      CALL RIN(-1.,W,RH)
      SC=-1.
      CALL PAT(XY,90.,-1.,SC)
      CALL PAT(XY,0.,-1.,SC)
      CALL PAT(ZYX,90.,-1.,SC)
      CALL PAT( ZYX,0.,-1.,SC)
      GO TO 10
99     STOP
      END
```

X - Y PLANE

PHI	EPHI	ETHETA	ETOTAL
SCALE 40 DB =	5.06138		
-180.00	17.729	-411.04	17.729
-175.00	17.451	-212.42	17.451
-170.00	16.562	-206.45	16.562
-165.00	14.867	-203.01	14.867
-160.00	11.816	-200.63	11.816
-155.00	5.2929	-198.85	5.2929
-150.00	-4.4025	-197.44	-4.4025
-145.00	10.601	-196.32	10.601
-140.00	16.231	-195.40	16.231
-135.00	19.854	-194.64	19.854
-130.00	22.548	-194.02	22.548
-125.00	24.695	-193.50	24.695
-120.00	26.476	-193.09	26.476
-115.00	27.994	-192.75	27.994
-110.00	29.313	-192.49	29.313
-105.00	30.474	-192.29	30.474
-100.00	31.509	-192.15	31.509
-95.000	32.440	-192.07	32.440
-90.000	33.283	-192.05	33.283
-85.000	34.052	-192.07	34.052
-80.000	34.756	-192.15	34.756
-75.000	35.403	-192.29	35.403
-70.000	35.998	-192.49	35.998
-65.000	36.547	-192.75	36.547
-60.000	37.052	-193.09	37.052
-55.000	37.516	-193.50	37.516
-50.000	37.941	-194.02	37.941
-45.000	38.326	-194.64	38.326
-40.000	38.672	-195.40	38.672
-35.000	38.979	-196.32	38.979
-30.000	39.247	-197.44	39.247
-25.000	39.475	-198.85	39.475
-20.000	39.663	-200.63	39.663
-15.000	39.810	-203.01	39.810
-10.000	39.915	-206.45	39.915
-5.0000	39.979	-212.42	39.979
0.	40.000	0.	40.000
5.0000	39.979	-212.42	39.979
10.000	39.915	-206.45	39.915
15.000	39.810	-203.01	39.810
20.000	39.663	-200.63	39.663
25.000	39.475	-198.85	39.475
30.000	39.247	-197.44	39.247
35.000	38.979	-196.32	38.979
40.000	38.672	-195.40	38.672
45.000	38.326	-194.64	38.326
50.000	37.941	-194.02	37.941
55.000	37.516	-193.50	37.516
60.000	37.052	-193.09	37.052
65.000	36.547	-192.75	36.547
70.000	35.998	-192.49	35.998
75.000	35.403	-192.29	35.403
80.000	34.756	-192.15	34.756
85.000	34.052	-192.07	34.052
90.000	33.283	-192.05	33.283
95.000	32.440	-192.07	32.440
100.00	31.509	-192.15	31.509
105.00	30.474	-192.29	30.474
110.00	29.313	-192.49	29.313


MICROSTRIP ANTENNAS
X-Y cut
θ = 90°
SCALE = 5.06138 dB
A/B = 1.5
F = 832 MHz
H = 1/16
ϵ_r = 2.5
-24.000
-16.000
-8.000
.000
8.000
16.000
24.000
32.000
40.000
48.00
32.00
24.00
16.00
8.00
-8.00
-16.00
-24.00
-32.00
-40.00

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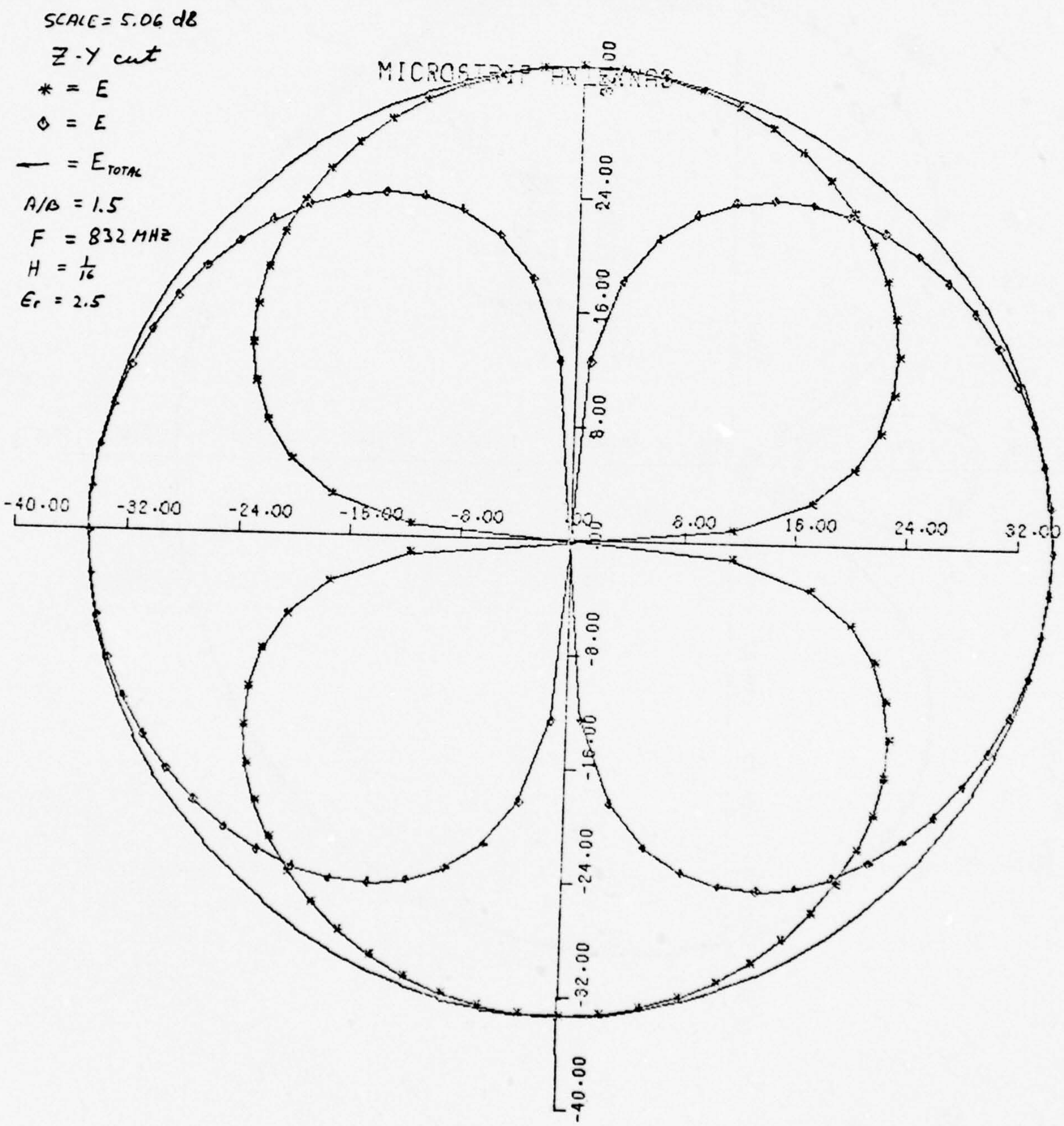

SCALE = 5.06 dB
Z-Y cut
* = E
◊ = E
— = E TOTAL
A/B = 1.5
F = 832 MHZ
H = 1/16
εr = 2.5
MICROSTRIP ANTENNAS
-40.00
-32.00
-24.00
-16.00
-8.00
8.00
16.00
24.00
32.00

```
      PROGRAM RESULTS(INPUT,OUTPUT)
C     THIS PROGRAM COMPILES ALL OF THE MEASURED DATA INTO A FORM WHICH LENDS
C     ITSELF TO ANALYSIS.
C     INPUT DATA IS AS FOLLOWS.
C     A, B, H , ER, MEASURED FREQ IN MHZ, MEASURED YO, MEASURED INPUT RESTANCE
C     AND AN INTEGER JJ WHERE  GROUPS OF JJ LINES ARE PRINTED WITH A BLANK LINE
C     BETWEEN EACH GROUP.
      REAL K,LAMDA,LAMDAG,MU,L,LOSSTAN,IM
      COMMON/B/A,B,F,H,ER
      COMMON/E/RS,RC,PI2,IM,L,PI,LAMDAG,LAMDA,LOSSTAN,ZO,PA,PB,P
      DIMENSION MFG(3),KOR(10)
      DATA MFG/2H3M,2HFL,2HCU/
      FREQU(H,ER,A,B)=5.901427165E9/(A*SQRT(1.+.61*(ER-1)*(B/H)**.1155)
     1+2.*H*SQRT(ER))
      MOD(I,J)=I-(I/J)*J
      IM=1.
      LOSSTAN=.001
      READ 11,(KOR(I),I=1,10)
      READ*,J
      IF(J.EQ.0) J=5
      CALL ANGL
      I=0
      PRINT 7
      PRINT 10
      PRINT 11,(KOR(I),I=1,10)
      PRINT 3
      KO=0
      XMULT=1.
      XPLUS=0.
1     READ*,A,B,H,ER,FMM,YO,RM,JJ
      FG=FMM*1.E-3
      IF(A.EQ.0.) GO TO 99
      IF(A.GT.0.) GO TO 20
      A=-A
      XMULT=XMULT**(1./KO)
      XPLUS=XPLUS/KO
      PRINT 4
      XMULT=1.
      XPLUS=0.
      KO=0
20     FM=FMM*1.E6
      IF(B.EQ.0.) GO TO 91
      ATOB=A/B
      I=I+1
      FC=FREQU(H,ER,A,B)
      F=FC
      CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(1,W)
      CALL RIN(-1.,W,RH)
      RI=RH*SIN(YC*P)**2
      IF(RI.EQ.0.) GO TO 92
      R9=RI
      CORREC1=RM/R9
      ESPEC=ER
      ER=DIELECT(FM,A,B,H)
      F=FM
      CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(1,W)
      CALL RIN(-1.,W,RH)
      RI=RH*SIN(YC*P)**2
      IF(RI.EQ.0.) GO TO 92
      FIX=(4.131666667E-3/H+1.5822-H*7.466026667)/(FG**(.32814+2.7515*H+
     1H*H*6.9077))
      RI=RI*FIX


      CORREC2=RM/RI
      RH=RH*CORREC2*FIX
      YC=ASIN(SQRT(50./RH))/P
      F=FC*1.E-6
      X=CORREC2
      XPLUS=XPLUS+X
      XMULT=XMULT*X
      KO=KO+1
      IF(X.LT.1.) X=1./X
30    YE=RH*(SIN((YC+.01)*P)**2-SIN((YC-.01)*P)**2)*.5
      PRINT 2,A,B,ATOB,H,ESPEC,YO,F,FMM,ER,ZO,RM,CORREC1,RI,CORREC2,YE,
     1 X,RH,YC,MFG(JJ)
      IF(MOD(I,J) .EQ. 0) PRINT 4
      GO TO 1
92    PRINT 6
      GO TO 99
91    PRINT 5
2     FORMAT(2(1X,F8.4),1X,F7.3,1X,F6.4,1X,F5.2,1X,F5.3,2(1X,F8.1),1X,
     1F5.2,2(1X,F7.3),1X,F6.3,1X,F7.1,1X,F6.3,1X,F5.2,1X,F5.3,1X,F6.0,
     2 1X,F5.3,1X,A2)
3     FORMAT(5X,*A*,8X,*B*,6X,*ATOB*,5X,*H*,5X,*ER*,4X,*YO*,4X,*F(MHZ)*
     1,3X,*F(MHZ)*,2X,*ER*,6X,*RIN*,5X,*RIN*,2X,*MEAS/*,5X,*RIN*,2X,
     2 *MEAS/*,2X,*.01## VSWR  R EDGE  NEW MFG*,/,35X,*SPEC*,
     3 10X,*CALC*,5X,*MEAS*,2X,*REQ#D*,3X,*CALC*,4X,*MEAS*,4X,*CALC*,3X,
     4 *CALC*,4X,*CALC*,1X,*ERROR*,16X,*Y0*,/)
4     FORMAT(1H )
5     FORMAT(*  ERROR B=0*)
6     FORMAT(*  ERROR  RIN=0*)
7     FORMAT(*1*)
8     FORMAT(80X,*XMULT=*,F7.5,5X,*AVE.=*,F7.5,/)
10    FORMAT(*0*)
11    FORMAT(10(A8))
   99 STOP
      END
```

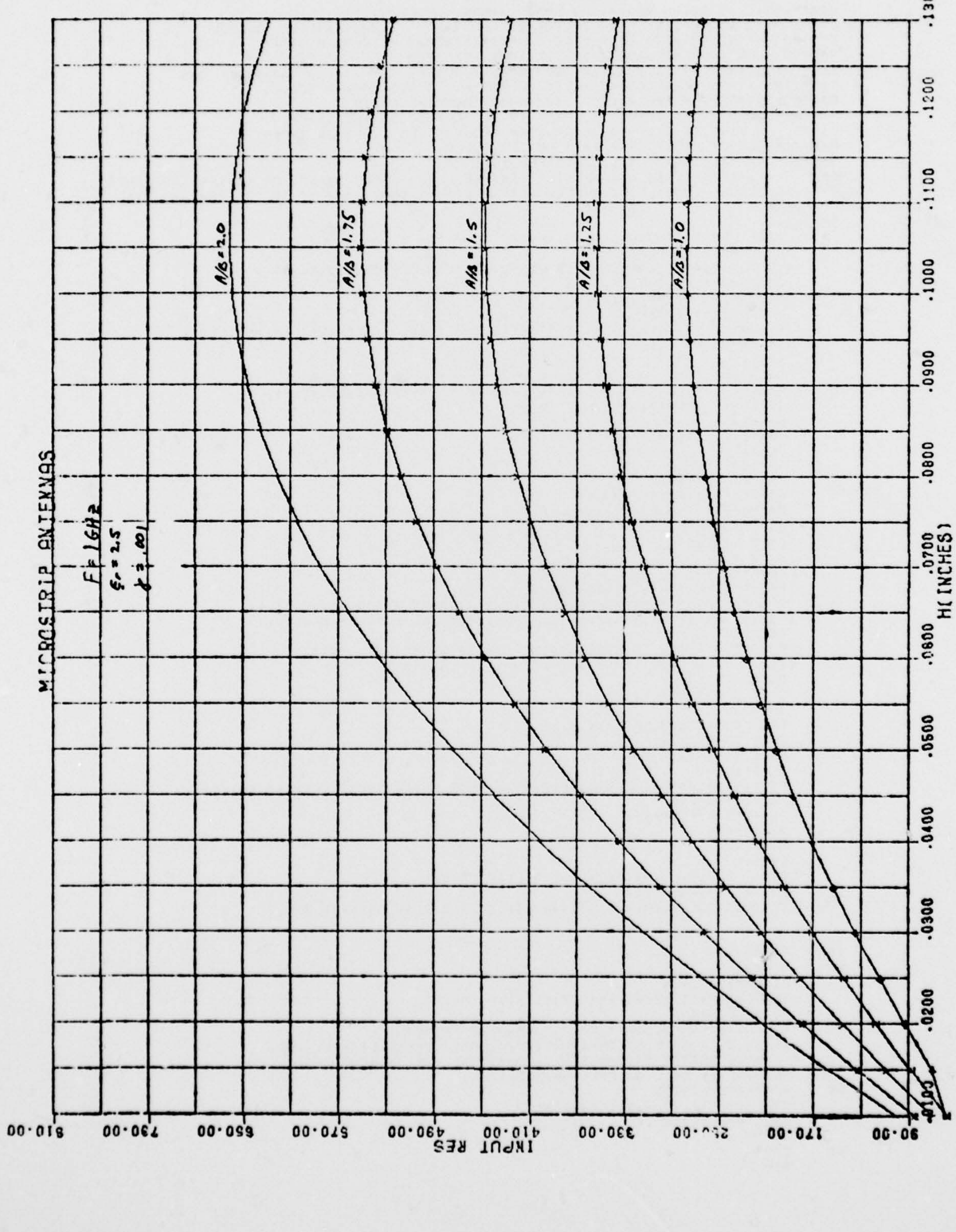
FIX=(4.13156667E-3/H+1.5922-H*7.46602066*1/(F**(.32916+?.7615*H+6.4077*H))

A	B	ATOB	H	ER SPEC	YC	F(HMZ) CALC	F(HMZ) MEAS	ER REQ'D	λg	RIN MEAS	MEAS/CALC	RIN CALC	MEAS/CALC	DIFF ERROR	COMP	R ERR	NEW MEG YC	
3.0000	1.5000	2.000	.0310	2.50	.500	1235.5	1248.8	2.45	4.6[illegible]1	116.000	1.671	89.6	1.241	2.93	1.241	451.	.325	3M
3.0000	1.5000	2.000	.0310	2.50	1.000	1235.5	1248.8	2.45	4.681	330.000	1.507	267.9	1.120	2.76	1.120	406.	.367	3M
3.0000	1.5000	2.000	.0310	2.50	1.500	1235.5	1250.1	2.[illegible]	4.686	470.000	1.484	362.6	1.103	2.73	1.103	400.	.350	3M
3.0000	3.0000	1.000	.0310	2.50	.500	1206.8	1240.3	2.37	2.442	43.500	1.576	36.9	1.180	1.65	1.180	178.	.543	3M
3.0000	3.0000	1.000	.0310	2.50	1.000	1206.8	1241.7	2.36	2.445	130.000	1.558	111.3	1.168	1.64	1.168	176.	.544	3M
3.0000	3.0000	1.000	.0310	2.50	1.500	1206.8	1242.5	2.36	2.447	175.000	1.549	150.7	1.161	1.63	1.161	175.	.546	3M
4.5000	3.0000	1.500	.0310	2.50	.750	809.9	850.8	2.27	2.495	50.000	1.691	46.0	1.087	1.21	1.087	203.	.750	3M
4.5000	3.0000	1.500	.0310	2.50	1.500	809.9	850.6	2.27	2.495	155.000	1.739	138.8	1.117	1.23	1.117	209.	.739	3M
4.5000	3.0000	1.500	.0310	2.50	2.250	809.9	850.6	2.27	2.495	190.000	1.581	187.0	1.016	1.16	1.016	150.	.779	3M
4.5000	3.0000	1.500	.1250	2.50	.750	813.9	810.8	2.52	8.877	100.000	.814	99.0	1.010	1.85	1.010	426.	.513	3M
4.5000	3.0000	1.500	.1250	2.50	1.500	813.9	816.8	2.48	8.945	330.000	.931	293.5	1.169	1.93	1.169	487.	.486	3M
4.5000	3.0000	1.500	.1250	2.50	2.250	813.9	819.2	2.47	8.973	450.000	.862	413.7	1.088	1.91	1.088	451.	.503	3M
3.0000	4.5000	.667	.1250	2.50	.500	1173.9	1190.0	2.47	6.154	27.600	.300	53.7	.503	1.17	1.988	119.	.710	3M
3.0000	4.5000	.667	.1250	2.50	1.000	1173.9	1191.0	2.43	6.213	82.500	.297	163.1	.506	1.15	1.977	117.	.715	3M
3.0000	4.5000	.667	.1250	2.50	1.500	1173.8	1198.8	2.39	6.254	110.000	.283	228.0	.482	1.09	2.073	111.	.762	3M
3.0000	3.0000	1.000	.1250	2.50	.500	1188.5	1194.8	2.47	8.959	55.000	.513	63.6	.867	1.95	1.153	242.	.475	3M
3.0000	3.0000	1.000	.1250	2.50	1.000	1188.5	1204.0	2.4[illegible]	9.033	175.000	.528	193.3	.905	1.99	1.105	249.	.467	3M
3.0000	3.0000	1.000	.1250	2.50	1.500	1188.5	1215.0	2.39	9.118	225.000	.480	269.3	.835	1.97	1.197	226.	.492	3M
3.0000	1.5000	2.000	.1250	2.50	.280	1213.2	1217.6	2.49	16.563	59.000	.684	50.3	1.176	3.80	1.176	791.	.257	3M
3.0000	1.5000	2.000	.1250	2.50	.500	1213.2	1219.3	2.47	16.598	210.000	.775	151.0	1.324	4.05	1.324	879.	.242	3M
3.0000	3.0000	1.000	.1250	2.50	.330	1188.5	1189.4	2.50	8.919	23.400	.478	29.2	.802	1.85	1.246	225.	.493	3M
3.0000	2.4000	1.250	.1250	2.50	.300	1196.5	1198.3	2.49	10.929	29.100	.556	30.9	.941	2.38	1.063	337.	.399	3M
3.0000	2.0000	1.500	.1250	2.50	.260	1203.0	1209.[illegible]	2.49	12.865	27.900	.555	29.6	.944	2.73	1.060	427.	.351	3M
3.0000	1.7100	1.754	.1250	2.50	.230	1208.6	1209.2	2.50	14.740	31.700	.647	28.8	1.101	3.35	1.101	616.	.293	3M
3.0000	1.5000	2.000	.1250	2.50	.210	1213.2	1215.5	2.49	16.553	25.200	.514	28.7	.879	3.26	1.138	584.	.298	3M
3.0000	3.0000	1.000	.0620	2.50	.460	1210.6	1231.8	2.41	4.712	49.600	1.031	50.5	.983	2.03	1.318	243.	.462	3M
3.0000	2.4000	1.250	.0620	2.50	.410	1219.4	1231.6	2.45	5.777	57.400	1.155	52.4	1.095	2.49	1.095	349.	.391	3M
3.0000	2.0000	1.500	.0620	2.50	.360	1226.6	1236.5	2.46	6.859	60.400	1.226	52.0	1.162	2.95	1.162	468.	.326	3M
3.0000	1.7100	1.754	.0620	2.50	.320	1232.7	1237.3	2.49	7.873	34.500	1.322	51.6	1.250	3.47	1.250	627.	.281	3M
3.0000	1.5000	2.000	.0620	2.50	.290	1237.8	1246.2	2.46	8.959	53.210	1.336	50.9	1.242	3.90	1.242	743.	.257	3M
3.0000	3.0000	1.000	.0310	2.50	.700	1206.8	1255.7	2.31	2.472	74.600	1.505	65.6	1.141	1.63	1.141	170.	.554	3M
3.0000	2.4000	1.250	.0310	2.50	.600	1216.1	1258.3	2.35	3.046	78.2[illegible]	1.604	64.6	1.210	1.97	1.210	270.	.463	3M
3.0000	2.0000	1.500	.0310	2.50	.550	1222.6	1255.8	2.37	3.610	98.800	1.580	70.4	1.262	2.36	1.262	307.	.402	3M
3.0000	1.7100	1.754	.0310	2.50	.480	1230.1	1261.3	2.39	4.191	78.630	1.539	69.0	1.156	2.52	1.156	347.	.377	3M
3.0000	1.5000	2.000	.0310	2.50	.430	1235.5	1265.4	2.28	4.744	98.000	1.743	66.6	1.340	3.03	1.340	481.	.313	3M
3.0000	2.4000	1.250	.1250	2.50	.460	1196.5	1196.6	2.50	10.913	41.000	.451	53.9	.761	2.13	1.314	273.	.443	FL
3.0000	2.0000	1.500	.1250	2.50	.320	1203.0	1206.6	2.49	12.857	45.000	.598	46.3	1.016	2.85	1.016	459.	.339	FL
3.0000	1.7100	1.754	.1250	2.50	.320	1208.6	1209.0	2.50	14.745	54.000	.579	54.8	.986	3.15	1.014	551.	.305	FL
3.0000	2.4000	1.250	.0620	2.50	.270	1219.4	1219.5	2.50	5.714	21.500	.955	23.8	.902	2.26	1.108	290.	.419	FL
3.0000	2.0000	1.500	.0620	2.50	.470	1226.6	1223.8	2.51	6.766	69.000	1.146	64.3	1.073	2.86	1.073	436.	.333	FL
3.0000	1.7100	1.754	.0620	2.50	.220	1232.7	1225.4	2.53	7.795	26.000	1.107	25.1	1.034	3.16	1.034	524.	.303	FL
3.0000	2.4000	1.250	.0310	2.50	.580	1216.1	1219.6	2.49	2.960	57.000	1.241	62.6	.910	1.65	1.099	179.	.533	FL
3.0000	2.0000	1.500	.0310	2.50	.390	1223.6	1220.0	2.51	3.507	36.200	1.290	39.4	.944	1.99	1.060	235.	.464	FL
3.0000	1.7100	1.754	.0310	2.50	.470	1230.1	1229.8	2.51	4.042	62.500	1.272	66.9	.934	2.25	1.071	287.	.417	FL
3.0000	1.5000	2.000	.0310	2.33	.430	1278.9	1266.3	2.39	4.740	81.000	1.445	66.4	1.069	2.67	1.069	384.	.357	DU
2.0000	1.5000	1.250	.1250	2.50	.280	1745.5	1769.[illegible]	2.43	15.835	62.500	.447	60.3	1.037	3.84	1.037	390.	.249	FL
2.0000	1.3333	1.503	.1250	2.50	.185	1756.5	1792.2	2.42	18.549	34.750	.435	34.1	1.016	4.32	1.016	451.	.223	FL
2.0000	1.1429	1.750	.1250	2.50	.310	1762.0	1792.8	2.41	21.144	130.000	.493	12.2	1.158	5.19	1.158	665.	.189	FL
2.0000	1.6000	1.250	.0620	2.50	.270	1815.7	1815.8	2.50	8.339	57.500	.821	60.7	.947	3.79	1.057	365.	.251	FL
2.0000	1.3333	1.500	.0620	2.50	.170	1828.0	1823.6	2.51	9.836	29.100	.799	31.9	.923	4.29	1.084	451.	.225	FL
2.0000	1.1429	1.750	.0620	2.50	.219	1834.6	1826.7	2.52	11.767	56.500	.900	58.0	1.131	5.38	1.131	682.	.181	FL
2.0000	1.5000	1.250	.0310	2.50	.260	1830.5	1822.8	2.52	4.376	39.700	1.204	39.1	1.041	3.17	1.041	261.	.294	FL
2.0000	1.3333	1.500	.0310	2.50	.220	1841.5	1828.6	2.54	5.139	36.000	1.187	35.1	1.027	3.62	1.027	326.	.261	FL
2.0000	1.1429	1.750	.0310	2.50	.240	1850.9	1837.6	2.55	5.926	56.000	1.269	51.1	1.097	4.24	1.097	429.	.225	FL
10.0000	6.0000	1.667	.1250	2.20	1.000	395.0	393.7	2.19	4.980	36.000	1.438	35.3	1.020	.80	1.020	389.	1.185	DU
10.0000	6.0000	1.667	.0620	2.20	1.250	389.4	396.6	2.[illegible]2	2.580	36.000	1.926	35.7	1.009	.62	1.009	256.	1.487	DU
10.0000	6.0000	1.667	.0310	2.20	1.720	383.1	397.1		1.331	44.000	2.232	33.0	1.032	.39	1.032	129.	2.144	DU

```
      PROGRAM RINVSH (OUTPUT,INPUT)
C***BASED ON MOE KALOISS PAPER ON MICROSTRIP ANTENNAS 1975
C***THIS PROGRAM PLOTS THE INPUT RESISTANCE AT RESONANCE VERSES THE SUBSTRATE
C***THICKNESS (H).  INPUT DATA IS AS FOLLOWS.
C***F,ER,LOSSTAN,HMIN,HMAX,NH,ABMIN,ABMAX,NAB,LL,Y1,Y2
C***F-FREQ IN HERTZ,   ER-DIELECTRIC CONSTANT    LOSSTAN-LOSS TANGENT
C***HMIN-MINIMUM H TO BE PLOTED    HMAX-MAXIMUM H TO BE PLOTTED
C***NH-NUMBER OF HEIGHTS (POINTS) TO BE PLOTTED
C*** NOTE.(HMAX-HMIN)/(NH-1)= CONVENIENT NUMBER FOR  THE H INTERVAL  AND
C*** (HMAX-HMIN)/24 =CONVIENIENT NUMBER FOR A NICE GRAPH SCALE.
C***ABMIN-MINIMUM A/B RATIO   ABMAX-MAXIMUM A/B RATIO
C***NAB-NUMBER OF RATIOS  (LINES) TO BE PLOTTED ON THE GRAPH.
C***LL- A LINE IS SKIPPED AFTER EACH GROUP OF LL LINES IS TYPED
C***Y1-MINIMUM VALUE OF Y AXIS ON THE GRAPH.
C***Y2-MAX VALUE OF Y AXIS ON GRAPH (RIN MAX)
C*** NOTE. (Y2-Y1)/18 = CONVENIENT INTERVAL FOR GRAPH SCALE. OR Y1=Y2=0 FOR AUTO
C*** SCALEING.  USUALLY A FULLER GRAPH RESULTS IF Y1 AND Y2 AFE DETERMINED BY
C*** HAND
C
      REAL LAMDA,LAMDAG,L,LOSSTAN,IM
      COMMON/B/A,B,F,H,ER
      COMMON/F/RS,RC,PI2,IM,L,PI,LAMDAG,LAMDA,LOSSTAN,ZO,PA,PB,P
      COMMON/F/EFF,DELTAF,GAIN
      DIMENSION RR(51),X(51)
      MOD(I,J)=I-(I/J)*J
      FREQU(H,ER,A,B)=5.9014271655E9/(A*SQRT(1.+.61*(ER-1)*(B/H)**.1155)
     1+2.*H*SQRT(ER))
      IM=1.
      CALL ANGL
1     READ*,F,ER,LOSSTAN,HMIN,HMAX,NH,ABMIN,ABMAX,NAB,LL,Y1,Y2
      IF(EOF(5LINPUT).NE.0) GO TO 99
      F=ABS(F)
       WL=1.1802854330E10/(F*SQRT(ER))
      WL=1.
       HMIN=HMIN*WL
       HMAX=HMAX*WL
      HINC=(HMAX-HMIN)/(NH-1)
      ABINC=(ABMAX-ABMIN)/(NAB-1)
      ATOB=ABMIN
      DO 20 J=1,NAB
      H=HMIN
      FF=F*1.E-9
      PRINT 5,FF,ATOB,LOSSTAN,ER,WL
5     FORMAT(//,6X,*FREQ(GHZ)=*,1PG12.4,3X,*A/B RATIO =*,1PG12.4,
     1 3X,*LOSSTAN =*,1PG12.4,3X,*ER=*,1PG12.4,3X,*WL=*,1PG12.4)
      PRINT 4
4     FORMAT(3X,*A*,15X,*B*,14X,*H*,13X,*R INPUT*,10X,*GAIN*,
     110X,*EFFICIENCY*,7X,*BANDWIDTH*,7X,*LAMDAG*)
      DO 10 I=1,NH
      CALL LENGTH(ATOB,20)
      YO=A/2.
      CALL CONSTAN(3.19E-8,1.47E6)
      CALL WATTS(1,W)
      CALL RIN(-1.,W,RH)
      FG=F*1.E-9
      FIX=(4.131666667E-3/H+1.5822-H*7.466026667)/(FG**(.32814+2.7515*H+
     1 6.9077*H*H))
      RI=RH*SIN(YO*P)**2
      RI=RI*FIX
      RR(I)=RI
      X(I)=H
      PRINT 3,A,B,H ,RI,GAIN,EFF,DELTAF,LAMDAG
3     FORMAT(8(1PG16.5))
      IF((MOD(I,LL).EQ.0).AND.((NH-I).GT.(LL/2))) PRINT 1425


1425  FORMAT(1H )
10    H=H+HINC
      II=NH*2./3.+.5
      SLOPE=(RR(II)-RR(1))*WL /((II-1)*HINC)
      PRINT 2,SLOPE
2     FORMAT(/,5X,*SLOPE=*,F6.0,*OHMS/WAVE LENGTHS*)
      IF(J.EQ.1) CALL CALCM1(NH,X,RR,0,HMIN,HMAX,Y1,Y2,12. ,9.,
     1 19HMICROSTRIP ANTENNAS,-19,9HH(INCHES),9,9HINPUT RES,9,1,18)
      IF(J.NE.1) CALL CALCM1(-NH,X,RR,-J)
20    ATOB=ATOB+ABINC
      CALL GRID(0.,0.,.5,.5,24,18)
      CALL CALCM1(0,0.)
      GO TO 1
99    STOP
      END
```

50



MICROSTRIP ANTENNAS
F = 1GHz
A/B=2.0
A/B=1.75
A/B=1.5
A/B=1.25
A/B=1.0
H(INCHES)
INPUT RES
.0100
.0200
.0300
.0400
.0500
.0600
.0700
.0800
.0900
.1000
.1100
.1200
.1300
90.00
170.00
330.00
410.00
490.00
570.00
650.00
730.00
810.00

FREQ(GHZ)= 1.000 A/B RATIO = 2.000 LOSSTAN = 1.0000E-03 ER= 2.500 WL= 1.000

A	B	H	R INPUT	GAIN	EFFICIENCY	BANDWIDTH	LAMDAG
3.5946	1.7973	1.00000E-02	99.678	3.4707	.63252	2.48354E+07	7.2144
3.6358	1.8179	1.50000E-02	156.92	3.9856	.71164	2.26570E+07	7.3095
3.6620	1.8310	2.00000E-02	212.20	4.2661	.75875	2.16320E+07	7.3746
3.6800	1.8400	2.50000E-02	264.53	4.4429	.79000	2.10552E+07	7.4232
3.6927	1.8464	3.00000E-02	313.56	4.5646	.81224	2.06953E+07	7.4613
3.7018	1.8509	3.50000E-02	359.19	4.6535	.82888	2.04550E+07	7.4922
3.7083	1.8542	4.00000E-02	401.43	4.7214	.84180	2.02865E+07	7.5179
3.7128	1.8564	4.50000E-02	440.30	4.7748	.85211	2.01639E+07	7.5395
3.7157	1.8578	5.00000E-02	475.86	4.8180	.86054	2.00719E+07	7.5578
3.7172	1.8586	5.50000E-02	508.17	4.8536	.86756	2.00012E+07	7.5736
3.7177	1.8589	6.00000E-02	537.27	4.8835	.87349	1.99455E+07	7.5873
3.7173	1.8587	6.50000E-02	563.23	4.9089	.87857	1.99008E+07	7.5991
3.7162	1.8581	7.00000E-02	586.09	4.9307	.88297	1.98641E+07	7.6094
3.7143	1.8572	7.50000E-02	605.88	4.9497	.88682	1.98335E+07	7.6184
3.7119	1.8559	8.00000E-02	622.65	4.9663	.89020	1.98074E+07	7.6262
3.7089	1.8545	8.50000E-02	636.43	4.9809	.89321	1.97847E+07	7.6329
3.7056	1.8528	9.00000E-02	647.24	4.9939	.89590	1.97647E+07	7.6388
3.7018	1.8509	9.50000E-02	655.12	5.0056	.89832	1.97466E+07	7.6439
3.6976	1.8488	1.00000E-01	660.09	5.0160	.90050	1.97301E+07	7.6482
3.6931	1.8466	.10500	662.17	5.0254	.90248	1.97145E+07	7.6519
3.6883	1.8442	.11000	661.37	5.0340	.90428	1.97000E+07	7.6549
3.6833	1.8416	.11500	657.71	5.0417	.90593	1.96860E+07	7.6575
3.6779	1.8390	.12000	651.21	5.0488	.90744	1.96723E+07	7.6595
3.6724	1.8362	.12500	641.87	5.0552	.90884	1.96589E+07	7.6610
3.6666	1.8333	.13000	629.71	5.0611	.91012	1.96457E+07	7.6622

SLOPE= 6845.OHMS/WAVE LENGTHS

FREQ(GHZ)= 1.000 A/B RATIO = 1.750 LOSSTAN = 1.0000E-03 ER= 2.500 WL= 1.000

A	B	H	R INPUT	GAIN	EFFICIENCY	BANDWIDTH	LAMDAG
3.5778	2.0445	1.00000E-02	84.327	3.6077	.65078	2.59768E+07	7.1810
3.6191	2.0681	1.50000E-02	132.74	4.0964	.72775	2.38465E+07	7.2762
3.6454	2.0831	2.00000E-02	178.08	4.3614	.77315	2.28529E+07	7.3415
3.6635	2.0934	2.50000E-02	222.05	4.5279	.80307	2.22994E+07	7.3902
3.6763	2.1007	3.00000E-02	262.63	4.6423	.82428	2.19579E+07	7.4285
3.6855	2.1060	3.50000E-02	300.37	4.7258	.84009	2.17327E+07	7.4596
3.6921	2.1098	4.00000E-02	335.29	4.7894	.85234	2.15769E+07	7.4853
3.6966	2.1123	4.50000E-02	367.44	4.8395	.86211	2.14652E+07	7.5071
3.6995	2.1140	5.00000E-02	396.86	4.8799	.87008	2.13828E+07	7.5256
3.7012	2.1150	5.50000E-02	423.59	4.9133	.87671	2.13205E+07	7.5415
3.7017	2.1153	6.00000E-02	447.70	4.9412	.88230	2.12724E+07	7.5553
3.7014	2.1151	6.50000E-02	469.21	4.9649	.88709	2.12345E+07	7.5672
3.7003	2.1144	7.00000E-02	488.17	4.9853	.89123	2.12040E+07	7.5776
3.6985	2.1134	7.50000E-02	504.60	5.0030	.89485	2.11790E+07	7.5867
3.6961	2.1121	8.00000E-02	518.54	5.0186	.89804	2.11581E+07	7.5946
3.6932	2.1104	8.50000E-02	530.01	5.0322	.90087	2.11402E+07	7.6015
3.6899	2.1085	9.00000E-02	539.04	5.0444	.90339	2.11245E+07	7.6075
3.6862	2.1064	9.50000E-02	545.64	5.0553	.90566	2.11104E+07	7.6127

```
      SUBROUTINE ANGL
C        THIS ROUTINE STORES ALL OF THE VALUES FOR THE SINE AND COSINE FUNCTIONS
C        THAT ARE USED THROUGHT THE PROGRAM
      COMMON/A/CO(145),SI(145),ANGINC
      ANGINC=4.36332313E-2
      DO 10 I=1,145
      ANG=ANGINC*(I-73)
      CO(I)=COS(ANG)
10    SI(I)=SIN(ANG)
      RETURN
      END
```

```
      SUBROUTINE CONSTAN(MU,SIGMA)
C        THIS ROUTINE CALCULATES MOST OF THE CONSTANTS USED THROUGHT THE PROGRAM
      REAL K,LAMDA,LAMDAG,MU,L,LOSSTAN,IM
      COMMON/A/CO(145),SI(145),ANGINC
      COMMON/B/A,B,F,H,ER
      COMMON/C/P2,K,PSB,PBK,PSA,PCK
      COMMON/D/PCON
      COMMON/E/RS,RC,PI2,IM,L,PI,LAMDAG,LAMDA,LOSSTAN,ZO,PA,PB,P
      PI=3.141592654
      R=63360
      PI2=2*PI
      LAMDAG=2*A+(4*H/SQRT(ER))
      LAMDA=1.180285433E10/F
      RS= SQRT(PI*F*MU/SIGMA)
      RC= RS*A/B
      ZO= 376.730366*H/(SQRT(ER)*B*(1.+1.735*(ER**(-.0724))*(H/B)**.836))
      K=PI2/LAMDA
      P=PI2/LAMDAG
      P2= P*P
      L= ZO/(F*LAMDAG)
      PCON=ZO/8.*(IM/LAMDA)**2
      ANGINC=4.36332313E-2
      PA= A*P*.5
      PSA=P*SIN(PA)
      PCK=K*COS(PA)
      PB=P*B*.5
      PSB=P*SIN(PB)
      PBK=K*COS(PB)
      RETURN
      END
```

```
      FUNCTION DIELECT(FM,A,B,H)
C        THIS FUNCTION CALCULATES THE DIELECTRIC CONSTANT REQUIRED TO GIVE THE
C        FREQUENCY OBTAINED IN AN ACTUAL TESTED ANTENNA
C        FM = MEASURED FREQUENCY IN HZ
C        A = THE LENGTH A IN INCHES
C        B = THE WIDTH B IN INCHES
C        H = THE SUBSTRATE THICKNESS IN INCHES
      F=FM*1.E-9
      BH=.61*(B/H)**.1155
      FH=(F*H)**2
      AF=(A*F)**2
      X=34.82684258+(BH-1)*AF
      Z=(4*FH-AF*BH)
      Y=X*Z-278.6147406*FH
      Z=Z*Z
      Y=-Y/Z
      DIELECT=Y-SQRT(Y*Y-X*X/Z)
      RETURN
      END




      SUBROUTINE LENGTH(ATOB,N)
C        THIS ROUTINE USES AN OPTIMIZED NEWTON ITERATION METHOD TO CALCULATE
C        ≠A≠ AND ≠B≠ FOR A GIVEN A/B RATIO
C          IF B DOES NOT EQUAL 0.0 WHEN THE ROUTINE IS CALLED, THEN B WILL BE
C        USED AS THE FIRST APPROXIMATION FOR B.
C        ATOB = THE RATIO A/B
C        N = MAXIMUM NUMBER OF ITERATIONS
      COMMON/B/A,B,F,H,ER
      IF(B.EQ.0.) B=5.75E9/(F*ATOB*SQRT(ER))
      K=0
      SER=SQRT(ER)
      ERM=ER-1.
      PSERM=.61*ERM
      CERM=.0352275*ERM
      TOP=5.901427165E9/F-2*H*SER
10    B1=B
      K=K+1
      BH=B/H
      BOT2=1.+PSERM*BH**.1155
      BOT=SQRT(BOT2)
      DBOT=CERM/(BH**.8845*BOT)
      FUNC=TOP/BOT-B*ATOB
      DFUNC=(-TOP)*DBOT/BOT2-ATOB
      B=B1-FUNC/(DFUNC*1.034)
      IF(K.GT.N) GO TO 20
      IF(ABS(1.-B1/B).GT.1.E-9) GO TO 10
      A=B*ATOB
      RETURN
20     A=B*ATOB
15     FORMAT(*  ERROR IN LENGTH    A=*,1PG20.10,*   B=*,1PG20.10,
     1 *   ERROR IN B =*,1PG20.10)
       PRINT 15,A,B,FUNC
      RETURN
      END
```

```
      SUBROUTINE PAT(CUT,ANGLE,OUT,SCALE)
C          THIS ROUTINE PRODUCES A  POLAR PATTERN ON THE CALCOMP PLOTTER.
C     CUT AND ANGLE DETERMINE THE PATTERN PLANE THROUGH THE ANTENNA.
C     CUT=XY MEANS THAT THE PLANE IS PARALLEL TO THE XY AXIS AND,
C     $ANGLE$=THETA
C     FOR EXAMPLE, A PLANE GOING THROUGH THE X-Y AXIS - ANGLE=90 DEGREES
C     CUT =ZYX MEANS THAT THE PLANE PASSES THROUGH THE Z AXIS  AND
C     $ANGLE$ = PHI
C     FOR EXAMPLE, A PLANE GOING THROUGH THE Z-Y AXIS - ANGLE=90  OR
C     Z-X AXIS  ANGLE= 0 DEGREES
C        THE PLOT IS SCALED SO THAT 40 DB PLOTTED IS ACTUALLY $SCALE$ DB.
C     IF $SCALE$ IS LESS THAN 0 WHEN $PAT$ IS CALLED, THEN THE VALUE FOR SCALE IS
C     CHANGED TO THE MAXIMUM GAIN OF THE ANTENNA PATTERN.
C           SCALE .LT. 0 AUTO SCALE
C           SCALE .GT. 0  40DB = SCALE
C           OUT.LT.0  PRINT AND GRAPH
C           OUT=1 PRINT ONLY
C            OUT=2 PRINT SCALE ONLY
C           OUT=3 NO PRINTING
      COMMON/A/CO(145),SI(145),ANGINC
      COMMON/PAT/EPXYX(73),EPXYY(73),ETXYX(73),ETXYY(73),ETOTXYX(73),ETO
     1TXYY(73)
      COMMON/G/PATK,XY,ZYX
      DIMENSION ETHXY(73),EPHXY(73),ETOTXY(73)
      IF(OUT.GT.2.) GO TO 90
      IF(CUT.EQ.XY) PRINT 1
1     FORMAT(40X,*X - Y     P L A N E*,/,10X,*PHI*,16X,*EPHI*,14X,*ETHETA
     1*,12X,*ETOTAL*,/)
      IF(CUT.EQ.ZYX) PRINT 100
100   FORMAT(40X,*X - Z     PLANE*,/,*THETA*,16X,*EPHI*,14X,*ETHETA*,13X,
     1 *ETOTAL*,/)
90    IP=ANGLE/2.5 +73
      IT=IP
      I=0
      XYMAX=(-1.E75)
      DO 10 K1=1,145,2
      IF(CUT.EQ.XY) IP=K1
      IF(CUT.EQ.ZYX) IT=K1
      I=I+1
      UH=U(IT,IP)
      TH=T(IT)
      ETHXY(I)=PATK*(UH*SI(IP)*CO(IT))**2
      EPHXY(I)=PATK*(UH*CO(IP)+TH*SI(IT))**2
      ETOTXY(I)=EPHXY(I)+ETHXY(I)
      IF(XYMAX.LT.ETOTXY(I)) XYMAX = ETOTXY(I)
10    CONTINUE
      XYDB=10.*ALOG10(XYMAX)
      IF(SCALE.GT.0.) XYDB=SCALE
      SCALE=XYDB
      DBCONXY=40.-XYDB
      IF(OUT.LT.3.) PRINT 3,XYDB
3     FORMAT(*  SCALE  40 DB =*,1PG20.6)
      I=0
      IF(OUT.GE.2.) GO TO 21
86    DO 20 IP=1,145,2
      I=I+1
      IF(EPHXY(I).NE.0.)EPHXY(I)=10.*ALOG10(EPHXY(I))+DBCONXY
      IF(ETHXY(I).NE.0.)ETHXY(I)=10.*ALOG10(ETHXY(I))+DBCONXY
      IF(ETOTXY(I).NE.0.)ETOTXY(I)=10.*ALOG10(ETOTXY(I))+DBCONXY
      PHI=5.*(I-1)-180.
      IF(OUT.LT.3.)PRINT 2, PHI,EPHXY(I),ETHXY(I),ETOTXY(I)
2     FORMAT(4(1PG19.5))
      IF(ETOTXY(I).LT.0.) ETOTXY(I)=0.
      IF(ETHXY(I).LT.0.)ETHXY(I)=0.


      IF(EPHXY(I).LT.0.) EPHXY(I)=0.
      EPXYX(I)=CO(IP)*EPHXY(I)
       EPXYY(I)=SI(IP)*EPHXY(I)
      ETXYX(I)=CO(IP)*ETHXY(I)
      ETXYY(I)=SI(IP)*ETHXY(I)
      ETOTXYX(I)=CO(IP)*ETOTXY(I)
      ETOTXYY(I)=SI(IP)*ETOTXY(I)
20      CONTINUE
      IF(OUT.EQ.1.) GO TO 21
      CALL CALCM1(73,ETOTXYX,ETOTXYY,0.,0.,0.,0.,0.9.  ,9.,19HMICROSTRIP ANTE
     1NNAS,-19,1H .1,1H .1,1,18)
      CALL CALCM1(-73,EPXYX,EPXYY,-2)
      CALL CALCM1(-73,ETXYX,ETXYY,-5)
      CALL CALCM1(0,0.)
21      RETURN
      END
```

```
      SUBROUTINE RIN(OUT,W,RH)
C        THIS SUBROUTINE COMPUTES THE INPUT RESISTANCE AT RESONANCE  UNADJUSTED
C        FOR THE INPUT POINT - YO
C        OUT .LT. 0. FOR NO PRINTOUT
C        OUT .GT. 0. FOR PRINTOUT OF RESULTS
C        W = WATTS OF RADIATED POWER
C        RH = THE UNADJUSTED INPUT RESISTANCE AT RESONANCE.
      REAL LAMDA,LAMDAG,L,LOSSTAN,IM
      COMMON/A/CO(145),SI(145),ANGINC
      COMMON/B/A,B,F,H,ER
      COMMON/E/RS,RC,PI2,IM,L,PI,LAMDAG,LAMDA,LOSSTAN,ZO,PA,PB,P
      COMMON/F/EFF,DELTAF,GAIN
      COMMON/G/PATK,XY,ZYX
      NAMELIST/RESULT/ZO,L,EFF,W,QR,QC,QD,QT,DELTAF,D,  RI ,RA,RC,RS,F,
     1 LAMDA,LAMDAG,IM,LOSSTAN,A,B,YO,H,ER,GAIN
      OMEGA=PI2*F
      RA=2*W/(IM*IM)
      QR=(OMEGA*L*A)/(2*RA)
      QC=(PI*ZO*B)/(LAMDAG*RS)
      QD=1./LOSSTAN
      QT=1./(1./QR+1./QC+1./QD)
      EFF=QT/QR
      DELTAF=F/QT
      RT=RA+2.*RC
      D=(ZO*PI/RA)*(((SIN(PA)+SIN(PB))/(LAMDA*P))**2)
      GAIN=10.*ALOG10(D*EFF)
      RH=2.*ZO**2/RT
10    PATK= EFF*PI*ZO*(IM/LAMDA)**2/(2.*W)
      IF (OUT.GT.0.) PRINT RESULT
      RETURN
      END
```

```
      FUNCTION SIMP(I,J)
C        THIS FUNCTION GENERATES THE PROPER COEFFICIENT FOR SUMMING TERMS IN A
C        SIMPSONS RULE INTEGRATION
C        J = TOTAL NUMBER OF TERMS IN THE SUM
C        I = THE NUMBER I OF THE I≠TH TERM BEING SUMED
      SIMP=2.
      A=I/2.
      II=I/2
      IF(II.EQ.A)SIMP=4.
      IF((I.LT.2).OR.(I.GE.J))SIMP=1.
      RETURN
      END
```

```
      FUNCTION T(IT)
C        THIS FUNCTION COMPUTES A CONVIENIENT INTERMEDIATE NUMBER
C        IT - REFERS TO A PARTICULAR ANGLE FOR THETA
      REAL K
      COMMON/A/CO(145),SI(145),ANGINC
      COMMON/B/A,B,F,H,ER
      COMMON/C/P2,K,PSB,PBK,PSA,PCK
      BKC=K*B*CO(IT)*.5
      T3=PSB*COS(BKC)
      T4=PBK*SIN(BKC)*CO(IT)
      T8=P2-(K*CO(IT))**2
      T=(T3-T4)/T8
      RETURN
      END
```

```
      FUNCTION U(IT,IP)
C        THIS FUNCTION COMPUTES A CONVIENIENT INTERMEDIATE NUMBER
C        IT - REFERS TO A PARTICULAR ANGLE FOR THETA
C        IP - REFERS TO A PARTICULAR ANGLE FOR PHI
      REAL K
      COMMON/A/CO(145),SI(145),ANGINC
      COMMON/B/A,B,F,H,ER
      COMMON/C/P2,K,PSB,PBK,PSA,PCK
       AK=K*A*SI(IT)*SI(IP)*.5
      U2=PSA*COS(AK)
      U3=PCK*SIN(AK)*SI(IT)*SI(IP)
      U5=P2-(K*SI(IT)*SI(IP))**2
      U=(U2-U3)/U5
       RETURN
      END
```

```
      SUBROUTINE WATTS(NT,W)
C        THIS SUBROUTINE COMPUTES THE RADIATED POWER BY USING SIMPSONS RULE TO
C        INTEGRATE WITH PHI, AND THEN USING FILON≠S METHOD TO INTEGRATE WITH
C        THETA.
C        NT = 1 FOR HALF SPHERE INTEGRATION ( AS KALOI SUGGESTS)
C        NT = 2 FOR FULL SPHERE INTEGRATION
C        W = WATTS OF RADIATED POWER
      COMMON/A/CO(145),SI(145),ANGINC
      COMMON/D/PCON
      DIMENSION Y(38),G(38),AX(38)
      IF((NT.GT.2).OR.(NT.LT.1))GO TO 40
      IF(CO(80) .LT. .5) CALL ANGL
      XANG=2.*ANGINC
      M1=73
      M2=145
      W=0.
      N=0
30    N=N+1
      J=0
      DO 10 IT=M1,M2,2
      J=J+1
      AX(J)=ANGINC*(IT-73)
      TH=T(IT)
      I=0
      G(J)=0.
      DO 20 IP= 37,109,2
      I=I+1
      UH=U(IT,IP)
20    G(J)=G(J)+((UH*CO(IP)+TH*SI(IT))**2+(UH*SI(IP)*CO(IT))**2)*SIMP(I,
     1 37)
10    G(J)=G(J)*XANG/3.
      W=W+ABS(XFIL(AX,G,Y,XANG,37,1.,1)*PCON)
      M1=1
      M2=73
      IF(N.LT.NT) GO TO 30
      RETURN
40    PRINT 1,NT
      NT=0
      NT=1/NT+1/NT+1
      RETURN
1     FORMAT(*  NT=*,I20,* ERROR   NT IS AN INTEGER*)
      END
```

```
      FUNCTION XFIL(T,F,Y,TH,NT,X,J)
C        THIS ROUTINE COMPUTES THE INTEGRAL OF SIN OR COS FUNCTIONS OF THE FORM
C        G(X)=INTEGRAL( F(T)*SIN(X*T) )DT FROM T1 TO TN
C        USING FILON≠S METHOD.
C        T = ONE DIMENSIONAL ARRAY (DIM GREATER THAN NT) CONTAINING VALUES OF T
C        F = ONE DIMENSIONAL ARRAY (DIM GREATER THAN NT) CONTAINING VALUES OF
C            F(T)
C        Y = ONE DIMENSIONAL ARRAY (DIM GREATER THAN NT) USED BY TH ROUTINE
C        TH = SPACING BETWEEN POINTS IN RADIANS
C        NT = NUMBER OF POINTS
C        X = THE PARAMETER IN ≠SIN(X*T)≠
C        J = 1 FOR SIN FORM
C        J = 2 FOR COS FORM
      DIMENSION T(1),F(1),Y(1),ALPHA(9),BETA(9),GAMMA(9)
      COMMON/A/CO(145),SI(145),ANGINC
      DATA (ALPHA(I),I=1,9)/0.,-.000000000001724,.000000000143307,
     1-.000000009396835,.000000469884174,-.000017102239324,.0004232804232
     28,-.006349206349206,.044444444444444/,(BETA(I),I=1,9)/-.000000000
     332325,.000000002395272,-.000000137820244,.000005920000592,-.0001795
     473512907,.003527336860367,-.038092538095238,.133333333333333,
     5.666666666666667/,(GAMMA(I),I=1,9)/0.,-.000000000000180,.000000000
     6042824,-.000000007708341,.000001002084335,-.000088183421517,.00476
     719047619005,-.133333333333333,1.333333333333333/
      M= MOD(NT,2)
      IF(M.EQ.0) GO TO 66
      THETA= X*TH
      A=B=G=0.
      IF(THETA.GE..75) GO TO 3
      THETA2= THETA**2
      B= .000000000000349*THETA2
      DO 4 I=1,8
      A= (A+ALPHA(I))*THETA2
      B= (B+BETA(I))*THETA2
    4 G= (G+GAMMA(I))*THETA2
      A= (A+ALPHA(9))*THETA*THETA2
    3 B= B+BETA(9)
      G= G+GAMMA(9)
       IZ1=X*T(1)*22.9183118 +73.
      IZN=X*T(NT)*22.9183118 +73.
      IF(J.EQ.1) GO TO 6
    7 DO 8 K=1,NT
      IZ=X*T(K)*22.9183118 +73.
    8 Y(K)= F(K)*CO(IZ)
      XF=(F(NT)*SI(IZN)-F(1)*SI(IZ1))*A
      GO TO 9
    6 DO 5 K=1,NT
      IZ=X*T(K)*22.9183118 +73.
    5 Y(K)= F(K)*SI(IZ)
      XF=(F(NT)*CO(IZN)-F(1)*CO(IZ1))*(-A)
    9 SUM= (Y(1)+Y(NT))/2.
      NT1= NT-1
      DO 10 K=3,NT1,2
   10 SUM= SUM+Y(K)
      XF= XF+B*SUM
      SUM= 0.
      DO 11 K=2,NT,2
   11 SUM= SUM+Y(K)
      XF= XF+G*SUM
      XFIL= XF*TH
      RETURN
   66 XFIL= 0.
      PRINT 100,NT
  100 FORMAT(1H0,17HNUMBER OF POINTS=,I10,36H MUST BE ODD  XFIL SET EQUA
     1L TO ZERO)

      RETURN
       END
```

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